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THE INTRINSIC MUSCLES OF THE MAMMALIAN FOOT. By D. J. CUNNINGHAM, M.D., *Senior Demonstrator of Anatomy, University of Edinburgh.*[1] (PLATE I.)

IN a paper which recently appeared in this *Journal,*[2] I called attention to the fact that the intrinsic muscles of the manus of certain of the Marsupialia might be considered to consist of three groups—*(a)* a palmar group of adductors, *(b)* an intermediate group of flexores breves, and *(c)* a dorsal group of abductors, according to the plane which they occupy as we dissect from the palmar to the dorsal aspect of the hand. Each digit is furnished with three muscles, each of which exercises its own independent action upon it. It derives an adductor from the palmar layer, an abductor from the dorsal layer, and a flexor brevis from the intermediate layer. The medius is an exception to this rule, inasmuch as two of its muscles belong to the dorsal layer.

In making inquiry into the arrangement of the corresponding muscles of the pes, I have extended my investigations over a much wider field than in the case of the manus. Through the kindness of Professor Turner, who placed the stores of the Anatomical Museum of this University at my disposal, I have been

[1] Incorporated with this paper is a description of the intrinsic muscles of the pes of the Cuscus and Thylacine. This is a portion of the Memoir upon the Anatomy of the Marsupialia which I am preparing for the Reports of the "Challenger" Expedition, and is published by permission of the Lords Commissioners of the Treasury.

[2] "Intrinsic Muscles of the Hand of the Thylacine, Cuscus, and Phascogale," *Journ. of Anat. and Phys.* vol. xii.

able to examine a large number of different kinds of mammalian feet, and in this way to arrive at certain conclusions regarding the general disposition of the muscles in question.[1]

I will begin by stating briefly what these conclusions are, and then bring forward the facts upon which they are based.

I. That the typical arrangement of the intrinsic muscles of the pes is the same as in the hand, and that this arrangement is seen to best advantage in the feet of certain of the Marsupialia. In these animals the muscles are disposed in three layers: (1) a *plantar layer* of adductors; (2) an *intermediate layer* of flexores breves; (3) a *dorsal layer* of abductors.[2] Deviations from the typical arrangement of these muscles may take place either by suppression or by fusion of certain of the elements of the different layers. Fusion of the constituents of the intermediate and dorsal layers is extremely common, whilst fusion between the plantar and intermediate muscles is a very rare occurrence.[3]

II. The presence of an opponens muscle is not accounted for in the foregoing disposition of the intrinsic muscles. When present it may be regarded as being derived from one of two sources. Most commonly it is a development from the flexor brevis, but it may also proceed, as in many of the carnivora, from the plantar layer, and thus be associated with the adductors.

III. The last point which I am anxious to prove is, that in many animals the relation of the intrinsic muscles to the metatarsal bones, both as regards their origin and position, corresponds with transitory conditions in the foot of the human embryo.

[1] The term *intrinsic* does not include the extensor brevis digitorum, the flexor brevis digitorum, the accessorius, nor the lumbricals.

[2] The abductors and adductors do not act with reference to a line drawn through the second digit, as in the human foot, but with reference to one drawn through the medius. The only exception to this rule that I have met with in my dissections is the Cuscus, which in this respect resembles man.

[3] Professor Humphry, in his "Memoir upon the Myology of the Orycteropus Capensis" (*Journ. of Anat. and Phys.* May 1868), alludes in a footnote to this typical arrangement, and he singles out the rabbit as affording a good example. In this animal, however, the dorsal and intermediate muscles have undergone partial fusion, and it does not exhibit the disposit on so well as the marsupial hand or foot.

I. Let us take up the first of these generalizations, and examine the facts upon which it is founded. We will begin with the Thylacine, a carnivorous marsupial, in which the pes closely resembles that of the dog. The hallux is quite rudimentary, but in connection with the remaining four digits the typical disposition of the intrinsic muscles in three layers is very manifest.

The Plantar Layer consists of three muscles, which have as their function the adduction of the toes towards a line drawn through the medius. They are: (1) the adductor indicis; (2) the adductor annularis; (3) the adductor minimi digiti. They all arise in the middle line of the foot from the fibrous structures at the base of the metatarsus, and they diverge from each other so as to reach their respective points of insertion.

The Intermediate Layer.—The muscles composing this layer are four in number, and are placed one upon the plantar surface of each metatarsal bone; but further, each muscle consists of two slips which may arise separately or by a common origin from the base of the metatarsal bone with which it is associated. At the root of the toe the two slips embrace the base of the proximal phalanx, and are inserted one into each sesamoid bone, and sometimes also into the extensor tendon as well.

These muscles, then, are true flexores breves when the two slips act in unison. When they act independently of each other, however, they will exercise an abducting or adducting influence according to the slip employed.

The Dorsal Layer includes the four dorsal interossei, the abductor minimi digiti, and the abductor ossis metatarsi minimi digiti.

The dorsal interossei cannot be properly studied unless we throw forward both the plantar and intermediate muscles. They are then seen to be prismatic, one-headed muscles, lying in the interosseous spaces, but only reaching for a short distance upwards between the bones; indeed, they are more plantar than dorsal in their relation to the metatarsus. They spring from the bases of the metatarsal bones, and are inserted so as to abduct the toes from a line drawn through the medius. They correspond, therefore, in their insertions with the same muscles in the human hand.

But with this group of muscles we also place the abductor

minimi digiti and the abductor ossis metatarsi minimi digiti, both of which are present in the foot of the Thylacine.

The *abductor minimi digiti* arises from the outer aspect of the tuberosity of the os calcis, and soon ending in a long, slender tendon, it is inserted into the fibular side of the base of the proximal phalanx of the minimus.

The *abductor ossis metatarsi minimi digiti* is more strongly marked than the preceding muscle, and has the usual insertion into the base of the fifth metatarsal bone.

In the Cuscus—one of the phalangers—the position of the hallux at right angles to the long axis of the foot, so as to oppose the other toes, somewhat disconcerts the typical arrangement of the muscles in so far as this digit is concerned. Still, sufficient indications remain to justify the conclusion that its three muscles, viz., the abductor, flexor brevis, and abductor, belong one to each of the three layers that we have laid down as typical.

The *plantar layer* consists of three muscles, viz.: (1) adductor hallucis; (2) adductor minimi digiti; (3) adductor annularis.

The adducting muscles of both manus and pes in all animals show a strong tendency to place themselves obliquely, or even at right angles, to the digit upon which they operate. In this manner they obtain a more powerful adducting influence. In the Thylacine the muscles of both hand and foot seek the middle line for their origin, and from this they radiate to their insertions. Again, in the human foot we see the transversus pedis placing itself at right angles, and the adductor hallucis obliquely, in relation to the great toe. But the most striking examples are to be seen in the hand, and more especially in the foot, of the Cuscus. In the hand the adductors arise from a median fibrous raphe placed over the middle metacarpal bone. In the foot adduction is effected towards a line drawn through the index, and the raphe is placed over the metatarsal bone which corresponds to this digit.

There is no adductor of the medius in the Cuscus, because this digit and the index are enclosed within the same covering of skin, and they have therefore no independent power of movement.

Adductor hallucis is the most powerful of the three muscles of

the hallux, and at the same time it is the most complex in its arrangement. It has a double origin—(*a*) from the base of the metatarsal bone of the index and from the tibial side of the proximal half of the fibrous raphe; (*b*) by a few fibres from the aponeurosis which clothes the dorsal aspect of the first dorsal interosseous muscle. The fleshy fibres soon arrange themselves into three slips which we may distinguish by the terms *plantar*, *intermediate*, and *dorsal*, and by these it is inserted. The plantar slip is attached to the outer of the two sesamoid bones along with the outer head of the flexor brevis hallucis. The intermediate slip ends in a long delicate tendon, and is inserted by this into the fibular side of the minute distal phalanx, and the dorsal portion ends in the extensor tendon.

The *adductor minimi digiti* arises by a wide origin not only from the greater extent of the fibular margin of the raphe, but also from the ligamentous structures at the base of the metatarsus. From this its fibres converge, and it is inserted into the tibial side of the base of the proximal phalanx of the minimus.

The *adductor annularis* is small in comparison with the preceding muscle, but it has the same triangular shape, and it is placed at right angles to the toe upon which it acts. It arises from the fibular border of the distal portion of the raphe, and also from the base of the first phalanx of the index. Crossing the base of the medius, it is inserted into the tibial side of the base of the proximal phalanx of the annularis.

The line towards which these muscles adduct the digits is manifestly one drawn through the index; and this, whilst it corresponds with the human foot, is an exception to the general rule that abduction and adduction are effected with reference to a line drawn through the medius.

The Intermediate Layer.—The *flexores breves.*—There are five muscles composing this layer, one to each toe, and they correspond with the same muscles in the Thylacine. Each muscle consists of two slips, and these are inserted one into each sesamoid bone at the base of the digit with which they are associated.

The *flexor brevis hallucis* is one of this group, but owing to the position of the hallux it is somewhat separated from its neigh-

bours. It arises by a single tendinous origin from the under surface of the scaphoid, and dividing into two heads it is inserted by these into the sesamoid bones at the base of the proximal phalanx of the hallux. The tibial insertion is associated with that of the abductor hallucis, and the fibular with that of the plantar part of the adductor hallucis.

The *Dorsal Layer.*—This group includes—(1) abductor hallucis; (2) abductor minimi digiti; (3) abductor ossis metatarsi minimi digiti; (4) the dorsal interossei.

The *abductor hallucis* is a strong muscle which arises from the cartilage of the sole and from a sesamoid bone which glides upon the plantar surface of the scaphoid. Its chief insertion is by fleshy fibres into the tibial sesamoid bone of the hallux, but it is also prolonged onwards by a slender tendon to the distal phalanx, to the tibial side of which it is fixed.

Abductor minimi digiti and *abductor ossis metatarsi* should be associated together, as the latter is evidently a development from the first. They both arise from the outer aspect of the os calcis, and they have the usual insertions.

The *dorsal interossei* are placed more in the sole of the foot than the corresponding muscles in the hand. They are one-headed, and show a tendency to fuse with the intermediate flexores breves.

The *first* or *abductor indicis* is the most powerful of the series, and is the only one which has an abducting action. It arises from the internal cuneiform bone, and is inserted into the tibial side of the base of the proximal phalanx of the index and also into the extensor tendon. The index and medius, as we have already seen, have no independent power of movement, and this muscle therefore acts upon both digits. The *second* is either absent or completely amalgamated with the inner head of the flexor brevis of the medius. The reason of this is obvious. The index and medius are enclosed within the same integumental covering, and can only move together. The *third* arises from the ligamentous structures at the base of the metatarsus and ends in a strong tendon which splits into two slips. These diverge from each other, and are inserted one into the fibular side of the base of the proximal phalanx of the medius, and the other into the tibial face of the base of the corresponding phalanx of the

annularis. The *fourth* is attached in precisely the same manner to the adjacent sides of the annularis and minimus.

The two latter muscles, then, can exercise no abducting influence whatever upon the medius and annularis. They can only act so as to approximate the digits into which they are inserted. Associated, however, with the third dorsal interosseous muscle is a small muscular slip lying upon its dorsal aspect and inserted so as to be capable of abducting the medius.

Opponens minimi digiti is a strong quadrate muscle placed obliquely in the foot. It arises from the outer margin of the plantar cartilage, and is inserted into the whole length of the fibular margin of the metatarsal bone, and also by a few fibres into the outer aspect of the base of the first phalanx of the minimus.

Of the carnivora I have examined the feet of the domestic dog, the dingo, the cat, the puma, the leopard, the lion, the otter, and the badger. In the two last the foot is pentadactylous, whilst in the others it is tetradactylous—the hallux being rudimentary.

Let us in the first instance direct our attention to the tetradactylous carnivora. In these the metatarsal bones are placed in such close apposition that the intrinsic muscles of the pes are situated almost entirely upon the plantar aspect of the metatarsus. In the dog (fig. 5), indeed, it is with difficulty that the point of a knife can be introduced into the interosseous spaces. In the cat, puma, leopard (fig. 6), and lion, whilst the bones are in actual contact towards the tarsus yet they open out towards their phalangeal extremities, and in the narrow eliptical spaces thus formed, the thin, sharp edges of the dorsal interossei may be seen reaching half-way up the interosseous spaces.

Owing to the crowding of the muscles into the sole, the clear definition between the three typical layers is to a great extent lost. None of the muscles are suppressed, but fusion has taken place between several which we have hitherto seen as separate and distinct factors.

Plantar Layer.—In all cases the adducting muscles remain as a distinct plantar layer, and they are arranged so as to adduct towards a line drawn through the medius. Generally they a

two in number, viz.: (1) adductor minimi digiti (fig. 2, *a.m.*); (2) adductor indicis (fig. 2, *a.i.*). Occasionally a third is to be found in the dog—an adductor annularis; but this is feebly developed, and always more or less fused with the tibial head of the flexor brevis of that toe. This seems to indicate that in the other animals this muscle is lost not by suppression but by fusion.

Associated with the plantar layer is the opponens minimi digiti (fig. 2, *o.m.*). It is a narrow band of fibres which arises in common with the adductor minimi digiti, and is inserted into the plantar face of the distal third of the shaft of the fifth metatarsal bone.

Dorsal and Intermediate Layers (fig. 2).—It is in the dorsal and intermediate layers of muscles that we find the greatest deviation from our type. The flexores breves ($f.^2$ to $f.^5$) and dorsal interossei ($d.^1$ to $d.^4$) owing to the more or less complete obliteration of the interosseous spaces have undergone a partial amalgamation; still there are traces left of a character sufficiently patent to enable the dissector to determine the complex nature of the muscles with which he has to deal. As a general rule, the fusion is complete towards the middle of the metatarsal bone, whilst towards the origin and insertion of the muscles more or less perfect separation can be effected. The mode of insertion of these muscles cannot be regarded as affording a true means by which they can be distinguished from each other. The dorsal interossei, it is true, are invariably inserted into the extensor tendon; but on the other hand, the flexores breves are not in all cases inserted into the sesamoid bones alone. One of the two slips is frequently inserted into the extensor tendon as well.

The fused flexores breves and dorsal interossei constitute a series of muscles which are frequently described as being bicipital, whilst in reality they are tricipital, and in the case of the medius quadricipital.

The dorsal interossei are disposed so as to abduct the toes from a line drawn through the medius. In no case do they arise from the shafts of the metatarsal bones.

It is interesting to trace the different degrees of fusion which exist between the outer head of the flexor brevis minimi digiti

and the abductor minimi digiti in the different animals. In the dog the fusion is complete, and there is little or no trace of an abductor to be found; in the lion the abductor arises from the os calcis, and constitutes a separate muscle as far as the base of the fifth metatarsal bone, but here it becomes partially amalgamated with the outer head of the flexor brevis; in the puma, cat, and leopard (fig. 2, *ab.*), the abductor remains distinct throughout.

Passing now to the pentadactylous carnivora, we find that the otter (fig. 1) and badger in the disposition of the intrinsic muscles of the pes approach very closely to the typical arrangement. The muscles are all placed in the sole, but still they remain separated from each other, and the three layers can be distinguished without any difficulty. The plantigrade character of a foot has apparently no effect in regulating the relation which exists between the intrinsic muscles and the metatarsus. In the badger the plantar position of these muscles is quite as well marked as it is in the otter and other digitigrade carnivora.

The squirrel, hedgehog, and rabbit closely resemble the tetradactylous carnivora in the general arrangement of their intrinsic pedal muscles. The adductors constitute a distinct plantar layer, whilst the flexores breves and dorsal interossei are more or less completely fused. In the course of my dissections, however, I have met with two very aberrant forms which require a more extended notice. I refer to the Dasypus sexcinctus (fig. 3) and the Bathyergus capensis (fig. 4).

The foot of the former (fig. 3) is of peculiar interest from the fact that, except in the case of the hallux and minimus, there is a complete suppression of the intermediate flexores and the dorsal interossei. The plantar adducting muscles, however, are well represented. They are four in number, viz.: (1) adductor hallucis (*a.h.*); (2) adductor minimi digiti (*a.m.*); (3) adductor indicis (*a.i.*); (4) adductor annularis (*a.a.*). They adduct the toes towards a line drawn through the medius. Only two members of the intermediate group are to be found, viz., the flexor brevis hallucis ($f.^1t.$ $f.^1f.$) and the flexor brevis minimi digiti ($f.^5$). The former is well developed, and has the usual bicipital character, although the tibial head is to a

certain extent fused with the abductor hallucis (*ab.h.*). The flexor brevis minimi digiti (*f.*[5]) is an extremely minute and single slip of muscular fibres, and can have little or no action upon the digit into which it is inserted. The dorsal group is composed of three muscles, viz.: the abductor hallucis (*ab.h.*), the abductor minimi digiti (*ab.*), and the abductor ossis metatarsi minimi digiti (*a.o.*).

The *abductor hallucis*, as we have seen, is to a certain extent fused with the tibial head of the flexor brevis. They soon separate, however, and the abductor is inserted by a long narrow tendon into the tibial side of the ungual phalanx of the hallux.

The *abductor minimi digiti* and *abductor ossis metatarsi* arise from the os calcis. The former is inserted by a long tendon into the fibular side of the distal phalanx of the minimus, whilst the latter is inserted into the base of the metatarsal bone of the same digit.

But the most remarkable feature in the pes of the Dasypus sexcinctus is that the place of the absent muscles is taken by fibrous bands (*f.b.*) which have precisely the same disposition and connections as those muscles of which they are the substitutes.[1]

A more extended account of the myology of the pes of this animal may be found (26th vol. *Lin. Trans.*) in an able memoir by Mr J. C. Galton. I cannot agree with Mr Galton, however, in the terms which he has applied to certain of the muscles. He looks upon the muscle which stretches between the os calcis and the base of the fifth metatarsal bone as being the abductor minimi digiti, and the muscle passing from the os calcis to the ungual phalanx of the minimus as being the flexor brevis. There can be little doubt that these mucles represent those after which I have named them, viz., the abductor ossis metatarsi and the abductor minimi digiti. The minute fasciculus (to which, by the way, he has affixed no name) is the true flexor brevis minimi digiti.

But, again, he is of opinion that the adductor minimi digiti is

[1] In the Ornithorhynchus a tendency to the same result is to be seen. The muscles have the typical arrangement, but the intermediate flexores and dorsal interossei are feebly developed, and the former show a considerable admixture of fibrous tissue with the muscular fibres.

the opponens. Such a conclusion I consider to be altogether untenable, as it is the very essence of an opponens that it should be inserted into the metatarsal bone, whilst this muscle is inserted into the distal phalanx.

The peculiarity of arrangement in thė pedal muscles of the Bathyergus (fig. 4) simply consists in a total absence of the plantar adducting muscles, and also of the dorsal abducting muscles. The intermediate flexores breves, however, are well developed—each consisting of two strong slips ($f.^1$ to $f.^5$).

Whether the plantar and dorsal muscles are absent from suppression or fusion with the flexors, it is impossible to make out. If it be due to the latter cause, there are certainly no traces of the fusion to be discovered.

The quadrumana must next claim our attention. Of these I chose for dissection the foot of a large monkey with a powerful opposable hallux, and also the foot of a lemur.

The adducting apparatus is remarkably powerful, and further, it is plantar in position. An interesting point in connection with these muscles, is the presence of a transversus pedis, or transverse adductor hallucis, almost blended with the true adductor hallucis. This bears upon the development of these muscles in the human foot. Dr Ruge of Heidelberg[1] has recently proved that the transversus pedis at an early stage of development of the human embryo lies in apposition with the true adductor, and that its transverse position in the adult is due to its travelling forwards towards the heads of the metatarsals. In the adult monkey, then, it is interesting to find the two muscles blended the one into the other.

The flexores breves and the dorsal interossei are partially fused as in the carnivora.

We are now evidently approaching the human foot, as the flexores of the index, medius and annularis are small and insignificant in size in comparision with the same muscles in other animals. Again, the dorsal interossei are bipenniform, arising from the shafts of the metatarsals and occuping the entire interosseous spaces.

In some of the smaller monkeys the interosseous muscles,

[1] "Processes in the Development of the Muscles of the Human Foot," by George Ruge, *Morphologisches Jahrbuch* (1878).

whilst they occupy the intermetatarsal spaces, are one-headed, and arise entirely from the base of the metatarsus.

In the lemur there is an oppenens minimi digiti.

We come now to the human foot; and if we have proved our point, the homologies of its intrinsic muscles are simple.

The adductor hallucis, transversus pedis, and the three plantar interossei are the representatives of the plantar layer in other animals. The flexor brevis minimi digiti and the flexor brevis hallucis are the only representatives of the intermediate series of flexores breves; and lastly, the abductor hallucis, the abductor minimi digiti, and the dorsal interossei constitute the dorsal layer.

It is true that the representatives of the three layers have lost their relative planes in the foot; but this is due partly to the arched condition of the metatarsus, whereby the short flexors, from their relation to the piers of the arch, have been thrown downwards, and partly to the suppression of the flexores breves in connection with the index, medius, and annularis, whereby the plantar interossei muscles have sunk deeply into the sole.

II. The question now arises: if the intrinsic muscles of the foot are laid down in three layers, to which of these does the opponens muscle belong?

It is necessary, however, before we inquire into this point, that we should have a clear understanding what the muscles are to which the term "opponens" should be applied. We need not look to its function for a true definition, for many of the opponens muscles have little or no opposing action. It is clearly the insertion which must be taken as the distinguishing feature, and we may define the term as being one which may be properly applied to any intrinsic muscle which is inserted into the shaft of a metatarsal bone.

An opponens hallucis is of very rare occurrence. It is found in some few cases, however, as, for example, in the ourang.[1] The opponens minimi digiti pedis is very common, and often very strongly marked. It may be regarded as belonging in some instances to the adducting or plantar layer, and in others to the intermediate or flexor layer. Thus Ruge of Heidelberg has conclusively shown that in the human foot (when present)

[1] St George Mivart in his *Lessons in Elementary Anatomy.*

it is a special development of the flexor brevis minimi digiti. In the lemur and phalanging marsupials it apparently has the same derivation.

On the other hand, many of the digitigrade carnivora afford a beautiful example of its association with the plantar layer. We have already seen it in the dog, cat, puma, leopard (fig. 2, *o.m.*), lion, and otter (fig. 1, *o.m.*), arising in common with the adductor minimi digiti.

III. The last point which we have to consider is one of great interest—viz., that the relation of the intrinsic muscles of the foot to the metatarsus in many animals corresponds to transitory conditions in the foot of the human embryo.

I have on more than one occasion in the course of this paper referred to the very important researches by Ruge of Heidelberg into the development of the muscles of the human foot.

In his memoir upon this subject, Ruge shows that the interossei muscles in the foot of the early embryo are plantar in position, and that the upward growth of the dorsal interossei and the formation of the interosseous spaces take place as a subsequent and gradual step. In three of the diagrams which illustrate the text, he gives representations of sections through the metatarsus at three different periods of development. In the first the metatarsal bones, with the exception of the first two, are in close apposition, and in consequence all the interossei muscles, excepting the first dorsal, are plantar in position. The second diagram is from a foot somewhat more advanced. It shows that as development progresses the metatarsal bones separaté from each other, and that simultaneously with this the dorsal interossei begin to shoot up between them like wedges. The third illustration gives a view of the relative position of the muscles and metatarsal bones as they are to be seen in the adult. The bones are widely apart from each other, and the muscles have reached the dorsum of the foot.

Among the lower mammals, the dog, in its adult condition, corresponds exactly with the first stage of the human embryo in the relation of its intrinsic pedal muscles to the metatarsus. The metatarsal bones are closely compressed together (fig. 5), and the muscles are entirely plantar in position.

The large majority of mammals never reach beyond the second stage of the foot of the human embryo in this respect. Let us take as an example the foot of the leopard (fig. 6). In this animal the metatarsal bones, whilst they are closely applied to each other towards the tarsus, open out slightly from each other towards their phalangeal extremities; and in the intervals between them the sharp edges of the dorsal interossei may be seen reaching half-way up the interosseous spaces (*d.*[2] to *d.*[4]).

Comparatively few animals correspond with the third stage of the human foot; still, certain monkeys approach very closely to man in this respect.

But there is also a relation between the human embryo and many of the adult animals in the mode of origin of the dorsal interossei. Ruge points out that in the early embryo these muscles are one-headed, and that it is only in a later stage that they acquire their bipenniform character and their origin from the metatarsal shafts. How similar is this to what we have seen to be the permanent condition in the great majority of mammals[1] (fig. 1, *d.*[1] to *d.*[4]).

The plate which accompanies this paper is the work of Mr J. Dunlop Dunlop, and I am greatly indebted to him for the careful and accurate manner in which he has delineated the various objects.

Explanation of Plate I.

Fig. 1. *Left Pes of the Otter* (plantar aspect), showing the intrinsic pedal muscles.

(*a.h.*) Adductor hallucis.	Plantar Group of Muscles.
(*a.i.*) Adductor indicis.	
(*a.m.*) Adductor minimi digiti.	
(*o.m.*) Opponens minimi digiti.	

[1] It is curious to find in an animal so low as the duck-bill platypus a closer approach to man in the mode of origin of its dorsal interossei muscles than in any of the other animals we have examined, with the exception of the quadrumana. The second and third dorsal interossei muscles in the pes of this animal are distinctly bipenniform, and arise from the shafts of the metatarsal bones. The first and fourth muscles are one-headed, and arise only from the base of the metatarsus.

These muscles are represented detached from their origins, and thrown forwards.

($f.^1$)	Flexor brevis hallucis.	Intermediate Group of Muscles.
($f.^2$)	Flexor brevis indicis.	
($f.^3$)	Flexor brevis medii.	
($f.^4$)	Flexor brevis annularis.	
($f.^5t.$)	Tibial head of the flexor brevis minimi digiti.	
($f.^5f.$)	Fibular head of the flexor brevis minimi digiti.	

The flexor brevis hallucis is represented by a single head; the other muscles of this group are seen to be bicipital.

($d.^1$ to $d.^4$)	The four dorsal interossei muscles.	Dorsal Group of Muscles.
($a.o.$)	Abductor ossis metatarsi minimi digiti.	

The abductor minimi digiti is absent as a distinct muscle. It is fused with the outer head of the flexor brevis ($f.^5f.$), and this is the reason why this slip is so large, and takes origin higher up in the foot than its neighbour ($f.^5t.$). An abductor hallucis is sometimes present as a distinct slip, but it was absent in the foot from which the drawing was taken.

Fig. 2. *Left Pes of Leopard* (reduced—plantar aspect). The plantar layer of muscles has been thrown forwards.

($a.i.$) Adductor indicis.
($a.m.$) Adductor minimi digiti.
($o.m.$) Opponens minimi digiti.

The dorsal and intermediate muscles are observed to be partially fused.

($f.^2$ to $f.^5$) The flexores breves.
($d.^1$ to $d.^4$) The dorsal interossei.
($ab.$) Abductor minimi digiti.
($a.o.$) Abductor ossis metatarsi.
($h.$) Rudimentary hallux.

Fig. 3. *Left Pes of Dasypus sexcinctus* (plantar aspect).

($a.h.$) Adductor hallucis.
($a.i.$) Adductor indicis.
($a.u.$) Adductor annularis.
($a.m.$) Adductor minimi digiti.

($f.^1t.$) Tibial head of flexor brevis hallucis.
($f.^1f.$) Fibular head of flexor brevis hallucis.
($f.^5$) Flexor brevis minimi digiti.

($ab.h.$) Abductor hallucis.
($ab.$) Abductor minimi digiti.
($a.o.$) Abductor ossis metatarsi.
($f.b.$) Fibrous bands representing the suppressed muscles.

Fig. 4. *Left Pes of Bathyergus capensis* (plantar aspect).

(*f.*[1] *to f.*[4]) The flexores breves.

The abducting and adducting muscles are absent.

Fig. 5. *Left Pes of Dingo* (dorsal aspect).—The close apposition of the metatarsal bones is seen.

Fig. 6. *Left Pes of Leopard* (dorsal aspect—reduced).—Shows that, whilst the metatarsal bones are closely applied towards the tarsus, they open out from each other towards their phalangeal extremities.

(*d.*[2] *to d.*[4]) Second, third, and fourth dorsal interosseous muscles.

THE ANATOMY OF THE INDIAN ELEPHANT. By L. C. MIALL, *Professor of Biology in the Yorkshire College, and Curator of the Leeds Museum;* and F. GREENWOOD, *Curator to the Leeds School of Medicine.*[1] (PLATES II. to V.)

PART III.

IN dealing with the myology of the Elephant, we thought it advisable, considering the want of any tolerably complete description, to note every important detail which came to light in the course of our dissection. It would be superfluous to treat all parts of the anatomy with the same fulness. The osteology, for example, has long been amply made known, nor would any student value minute descriptions of bones which can be so easily seen and handled. Other parts of the anatomy are known in various degrees of completeness; some thoroughly, some superficially, some hardly at all. Vulpian and Philipeaux have published a lengthy and elaborate description of the heart; Dr Morrison Watson has minutely described the male organs of generation, and other important viscera; the brain has been figured more than once; while scattered memoirs contain particulars of greater or less value respecting other organs. Under these circumstances we shall probably employ our space and the reader's time to the best advantage by a summary of what is already known, corrected and supplemented by our own observations. Although such anatomists as Cuvier, Camper, and Hunter have preceded us, there is still much to be gleaned, more than any single exploration of the field is at all likely to discover.

The osteology and dentition we propose to leave out altogether. Common text-books already contain descriptions sufficient for the naturalist or palæontologist.

ALIMENTARY CANAL AND ITS APPENDAGES.

MOUTH.

The gape of the mouth is small relatively to the bulk of the animal,—a fact which may receive explanation from the precision with which food is passed into the mouth by the proboscis, and the small part which the lips consequently play in the act of prehension. The upper lip has hardly any separate development, but seems a mere lateral expansion of the root of the trunk; the lower lip is small and pointed, its mucous surface

[1] Continued from vol. xii. p. 400.

forming a narrow groove or gutter in which the tongue is lodged. The cheeks are very capable of distention, but in their ordinary contracted state they enclose only a very small cavity.

The mucous membrane of the mouth is in general smooth; that of the palate in particular is quite smooth, and shows none of the transverse ridges which appear on the hard palate of the horse and ox. Two shallow triangular depressions placed symmetrically immediately in front of the fore edge of the hard palate lead to Jacobson's canals. The bony cavity in which the canals lie runs in the suture between the premaxillæ and maxillæ for 7 or 8 inches (Mayer gives 8 inches), taking a nearly straight direction upwards and backwards; it is furnished with a vertical cartilaginous septum and a cartilaginous lining. Each of the component canals is of about the diameter of a goose-quill, and is lined by an extension of the mucous membrane of the mouth. Camper (p. 48) says that these canals when pressed exude a sticky fluid.

Examination of skulls of different ages seems to show that Jacobson's canals are at first nearly horizontal, but that as the air-cells of the maxilla enlarge, the maxillo-premaxillary suture, and with it the canals, is tilted more and more, until it finally gets a steep slope forwards.

TONGUE.

The tongue is thick and rounded towards its base, tapering and pointed in front. Perrault describes it as 18 inches long, but in our young example it was much shorter. The tip is directed downwards, and lies almost invariably in the groove formed by the lower lip. All observation of the living animal seems to show that the tongue, like the lips, is of little importance in the act of feeding. The oral surface of the tongue ends behind in a prominent concave edge, which forms the front and lower boundary of the pharyngeal pouch. Towards the base are two, four, or more circumvallate papillæ of large size, while on the side, especially behind, are a number of wart-like eminences and mucous crypts.

SALIVARY GLANDS.

The parotid was small in our example, and measured only

4 inches by 3. Dr Watson gives 8 inches by 5 as the dimensions. The gland is connected by a fibrous band with the zygoma; it lies in the space below the zygoma and behind the ascending ramus of the lower jaw. Steno's duct passes out from near the middle of the gland; it is at first of about half an inch diameter, but gradually contracts to the size of a crow-quill. Close to its termination it pierces the *buccinator*, and finally opens into the mouth near the alveolar margin of the upper jaw by a simple rounded orifice without papilla.

No sub-maxillary gland was seen either by Dr Watson or ourselves, though it is described by Mayer. A small lobulated mass, lying between the *genio-hyo-glossi* and close to the symphysis of the mandible, may possibly be a sublingual gland, but we were unable to discover an efferent duct, or to satisfy ourselves as to the exact nature of the body.

Soft Palate.

The soft palate, which is hardly distinguishable from the base of the velum palati, extends backwards about 2 inches from the hind edge of the hard palate. Like the nasal passages immediately above, it is narrow from side to side. No *levator palati* was made out. The *tensor palati*[1] arises from the front and outer side of the upper part of the membranous section of the Eustachian tube. It is a small, spindle-shaped muscle enclosed in a sheath of fascia. At the groove of the hamular process it becomes tendinous and spreads out in the substance of the soft palate.

Pharynx.

The upward extension of the pharynx towards the nasal passages gradually narrows from side to side as it ascends. The antero-posterior dimension is much contracted in the neighbourhood of the soft palate. Above this level, the pharynx is prolonged into the nares in front, and is also continued for some distance backwards as a gradually diminishing cavity which extends beneath the basi-sphenoid to near its junction with the basi-occipital. The ultimate recess (the sinus of Morgagni) just admits the last joint of the forefinger.

[1] Dr Watson considers that this muscle is absent in the elephant.

The pharyngeal openings of the Eustachian tubes lie in the lateral walls of this part of the pharynx, about an inch above the hamular pterygoid process, and a little above the level of the hard palate. The orifices are large enough to admit the little finger. In its lower part each tube is almost entirely membranous. It runs upwards and a little outwards, and may be explored by a probe for 7 inches. We have been unwilling to destroy the surrounding parts for the sake of tracing the tube further. According to Camper's figures (pl. xiii. figs. 7, 8), the bony tube is about 2 inches long and the cartilaginous tube over an inch. The same author describes and figures an opening from the upper part of the cartilaginous tube into the nasal passage. We find no corresponding opening in the soft parts.

The common aperture of the posterior nares occupies a triangular space 4½ inches high and 2 inches wide. The hind edge of the septum is very thin, and deeply concave above.

Muscles of the Pharynx.

Constrictor pharyngis arises on each side from the thyro-hyal, from the posterior margin of the thyroid cartilage, and from the cricoid cartilage below the arytænoid facet. The fibres pass round the tube of the pharynx, and blend along the middle line behind. The uppermost (or anterior) fibres form a tolerably distinct bundle. The lower fibres curve upwards so as to leave a triangular gap, which is filled by a tapering median bundle of the longitudinal œsophageal fibres.

C. and L.—261, fig. 1 (s^1, x^2, z^2).

Stylo-pharyngeus arises from the internal surface of the anterior branch of the stylo-hyal, close to its origin. The muscle passes downwards along the side of the pharynx and is there inserted.

C. and L.—261, fig. 1 (v^1).

Palato-pharyngeus is largely developed. It arises from the palate and descends to the pharynx, forming a considerable part both of the soft palate and the velum palati. It is inserted laterally on the inner surface of the pharyngeal wall.

A symmetrical venous plexus, which arises by free communications between the internal jugular, internal maxillary, and

inferior palatine veins, lies at the back of the mouth, below the soft palate.

The entrance to the pharynx is bounded above by the antero-inferior edge of the velum palati (where its descending and horizontal portions meet); in front and below by the sharp, backward directed edge of the dorsum of the tongue; and laterally by the mucous membrane of the pharynx, with which are connected a number of scattered muscular fibres, and the yellow elastic pharyngeal wall. There is no *palato-glossus*. The passage is very narrow, and cannot in our young example be distended to admit a cylinder of 2 inches diameter.

The velum palati descends from the soft palate, but its chief extension, as in many other large quadrupeds, is horizontally backward. The free posterior edge passes so far back as slightly to overlap the epiglottis. On each side it is continued into a thin elastic fold, which is obliquely attached to the pharyngeal wall, sloping backwards. In the natural position of the parts, the posterior edge of the velum encloses an oval space, the longitudinal diameter being an inch and a half, the transverse somewhat less. Through this aperture the arytænoid cartilages project. The lower ends of the lateral bands of the velum are approximated, but they do not meet; and Dr Watson, therefore, in speaking of the "central" aperture of the soft palate, is to be understood as meaning "in the middle line." The position of the aperture is anatomically the same as in the human subject or as in the majority of mammalia, and altogether below the velum. There is no uvula, but we find a small vertical muscle in the middle line, passing from the soft palate, to be inserted into the back of the upper portion of the velum. This may represent an *azygos uvulæ;* its length does not exceed 2 inches.

The muscular layer of the velum palati forms part of the *palato-pharyngeus*. Its anterior fibres, arising from the palate, pass backwards and a little downwards, to be inserted into the inner surface of the elastic wall of the pharynx, near the free tip of the thyro-hyal. The posterior fibres gradually take a more and more transverse direction, and form the thin muscular sheet which lies in the horizontal valve of the velum. The lateral bands of attachment contain muscular bundles from the same

stratum. These bands are separated from the insertion of the anterior fibres of the *palato-pharyngeus* by a considerable elastic pouch, opening backwards into the pharynx, and lined by a continuation of the mucous membrane of that cavity.

Immediately in front of the epiglottis is a vertical transverse elastic fold, which projects from the floor, and especially from the sides, of the pharynx, but not so far as to materially obstruct the passage. Smaller secondary folds proceed backwards from this at right angles, passing longitudinally upon the floor of the pharynx outside the laryngeal aperture. When the pharynx is seen from above and behind, there are therefore visible three cavities on each side, divided from each other by mucous folds. In front of the epiglottis, behind the transverse fold, and inside the longitudinal secondary fold just described, is a small recess, with a small gland in its floor. To the outer side of this is a larger cavity, in which a larger gland can be seen; it is included between the transverse fold, the secondary longitudinal fold, and the lateral attachment of the velum. Between the lateral attachment of the velum and the proper pharyngeal wall is a third and much more capacious receptacle, which has been described in connection with the *palato-pharyngeus.*

The wall of the pharynx is largely composed of yellow elastic tissue, overlaid by the constrictor muscles. The *palato-pharyngeus* lies deeper, and is inserted into the inner surface of the elastic wall.

Dr Watson has described, in connection with the pharynx, a peculiar structure which throws light on a previously unexplained faculty of the elephant, viz., the power which the animal possesses, according to more than one competent observer, of withdrawing large quantities of water by inserting the tip of the trunk into the mouth. He observes that

"It is evident that were the throat of this animal similar to that of other mammals, this [withdrawal by the trunk] could not be accomplished, as the insertion of a body, such as the trunk, so far into the pharynx as to enable the constrictor muscles of that organ to grasp it, would at one give rise to a paroxysm of coughing, or were the trunk merely inserted into the mouth, it would be requisite that this cavity be kept constantly filled with water at the same time that the lips closely encircled the inserted trunk. The formation of the mouth of the elephant, however, is such as to prevent the trunk ever being

… entrance of air into … it, the pump-action …

… A, superior aperture of … B, root of tongue. … palate with larynx pro… through the centre. D, …

… part of the floor of … of the hyoid bone, … and distensible con… of the pouch. The … by the actions of … hyo-glossi muscles, … omologies of which I … ging from the middle … up, one on either … muscles forming the … the pouch may be … narrow interval exist… pouch from before

...tilage is thereby pre-
...ce. . . . An elephant
...draw water from his

...rictor. G, stylo-glossus.
...ishes the depth of the
...for the use of the wood-
...Turner.)

...ated directly into the
...d abdominal muscles,
... so as to prevent the
...his manner filled the
...k, the water contained
... means of a powerful
...y be withdrawn from
...serted into it. Now,
...water can be contained
...e already shown that
...ally to prevent this.
... the elevation of the
...The superior aperture
...iameter of the pouch
...muscular fibres of the
...ongue in front, which
...arp margin, we have
... a sphincter muscle,
...ed above its dilated
...ferred to, air is thus
...g then exhausted by
...e passages to be used
...er his body, or again

The chief difficulty attending this explanation springs from the small size of this pharyngeal pouch. In our example, which, it must be remarked, was by no means of full stature, the pouch could not be distended so as to hold a pint of water. This objection is not fatal to the hypothesis advanced by Dr Watson.[1] Regurgitation from the stomach may be effected slowly and continuously until the requisite supply is yielded. It seems to us that the pharyngeal pouch must be unimportant as a mere reservoir of fluid, but as a water-tight circular valve it may be essential to the process of withdrawal. Behind the velum palati is a somewhat larger cavity, but the entrance to the windpipe lies in its floor, and this is not therefore a very likely receptacle of fluid. If our examination of an immature elephant yields data in the least trustworthy, it is hard to suppose that even in the adult a gallon of water can be retained anywhere between the stomach and the proboscis.

We do not know enough of the habits of the living animal to say whether or not the food is moulded and lubricated into a bolus, but the form, structure, and glandular surface of the pharyngeal pouch would be well adapted to such a practice.[2]

[1] Dr Watson informs us that he considers the pharyngeal pouch unimportant as a mere reservoir, "though the presence of certain muscles not found in other animals would appear to indicate that the elephant possesses a certain power of increasing or diminishing the size of the pouch, and the necessity for this is by no means evident upon the supposition that the sphincter arrangement is the only *raison d'être* of this pouch."

[2] Professor Owen describes the back of the mouth of the Camel in these words:—"A broad pendulous flap hangs down from the fore part of the soft palate, and usually rests upon the dorsum of the tongue. The velum palati extends beyond this process some way down the pharynx, and terminates by a concave border. The pharynx behind the velum dilates into a sac. In the rutting male the palatal flap is greatly enlarged. I have found it extending 10 inches down the pharynx, passing below the margin of the soft palate and the opening of the larynx, into the œsophagus: in the living animal it is, at this season, occasionally protruded, with a belching noise, from the mouth. Its surface shows the pores of innumerable mucous crypts, and in the ordinary state, in both sexes, the flap may apply its own secretion, and water regurgitated from the storage cells of the stomach to the extended surface of the pharynx and root of the tongue so as to allay the feeling of thirst and help the animal to endure the long remissions of drinking to which it is liable in traversing the desert" (*Comp. Anatomy of Vertebrates*, vol. iii. p. 395). In transcribing these remarks, we desire to offer no opinion as to the validity of the explanation offered. The pharyngeal sac described in the camel may throw light on the similar structure in the elephant.

A number of pits in the mucous membrane of the floor and sides of the pharynx are doubtless glandular. They are altogether absent from the middle line, but become densely aggregated towards the root of the tongue on the sides of the pharyngeal floor. Similar glandular crypts line a pouch, in our example about an inch deep and half an inch in diameter,[1] which lies on each side in the lateral wall of the pharynx in front of the transverse fold described above. In the lateral spaces behind the transverse fold are other flattened glands.

The thyro-hyals support the pharyngeal wall laterally, and their expanded ends can be plainly felt upon its inner surface, in the recess behind and within the lateral attachment of the velum. Professor A. H. Garrod has remarked[2] that the basi- and thyro-hyals form a lower arch quite distinct from the bifurcate stylo-hyals, and he adds: "In the elephant, therefore, the deficiency of the lateral intermediate elements of the hyoid apparatus permits of a much greater movement of the base of the tongue than in the ungulata, whose nearly rigid stylo-hyals, epi-hyals and cerato-hyals can allow of little more than an antero-posterior movement of the base of the tongue in part of the circle of which the hyo-cranial attachment in the centre."

Œsophagus.

Dr Watson states that "the muscular fibres of the œsophagus are distinctly striated even down to the œsophageal opening in the diaphragm, and are arranged in two layers—an external, the fibres of which are distinctly longitudinal in direction; and an internal, which consists of two sets of spiral fibres, one of which passes from right to left, whilst the other passes in the opposite direction, and thus gives rise to a decussation of the fibres at all points."

Like Dr Watson, we found no trace of a muscle connecting the trachea with the œsophagus and stomach, such as was described and figured by Dr Harrison of Dublin.[3]

[1] Mayer found this pouch to be 3½ inches long and 1¼ wide.
[2] *Proc. Zool. Soc.* May 1875.
[3] *Proc. Roy. Irish Acad.* vol. iv. p. 133 (1847).

STOMACH.

An excellent figure of this viscus is given by Camper (pl. ix. fig. 1). Mayer's drawing is less satisfactory.

The stomach is smooth externally, elongate, and nearly straight. The cardiac end is much prolonged and tapering. A number of transverse nearly circular folds project inwards from the cardiac wall; they almost disappear when the stomach is greatly distended, and are at all times too shallow to serve as water-cells, though they have been figured and described as such.[1] The gastric follicles are most abundant towards the cardiac end, as Mayer has observed. In an adult elephant the stomach is little less than three feet long; the œsophagus enters near the middle but rather nearer the cardiac than the pyloric end. The pyloric valve is well developed.

INTESTINES.

"The duodenum is at first loosely suspended and convolute, as in some rodents; it is more closely attached at its termination. The mucous coat of the jejunum is thrown into small irregular folds, both transverse and longitudinal. There are oblong patches of agminate follicles. The termination of the ileum projects as a conical valve" [a very truncate cone] "into the cæcum. The longitudinal layer of muscular fibres is continued directly from the ileum upon the cæcum; but the circular layer accompanies the valvular production of the mucous membrane, and is there thicker than on the free gut. The large cæcum is sacculated on three longitudinal bands, which are continued some way along the colon."[2]

We find a number of aggregated glands, not unlike Peyer's patches, in the rectum. The occurrence so low down of what are probably absorbents may be partly explained by the slow alteration of food passed along the alimentary canal of the elephant. Even in the large intestine the original form of many pieces of vegetable food is retained, and grains of maize were recognisable in the colon of our example, as were hay and potatoes in the colon of that dissected by Camper.[3]

[1] Emerson Tennent, *Natural History of Ceylon*, p. 125; see also Perrault, as quoted by Buffon, *Hist. Nat.* vol. xi. p. 109.

[2] Owen, *Comp. Anat. of Vertebrates*, vol. iii. p. 457.

[3] Further observations are necessary before we can be satisfied that these appearances are not due to disease.

Hunter gives 17 feet as the length of the small intestine. Mayer makes it 37 feet, while he gives the total length of the intestines as 75 feet. Professor Owen's measurements, taken from a young Indian elephant about 7 feet high at the shoulder, are as follows[1]:—

	Ft.	In.
Length of the small intestines, . .	38	0
Circumference of ditto., ...	2	0
Length of cæcum, ...	1	6
Circumference of cæcum, . . .	5	0
Circumference of colon, ...	6	0
Total length of colon and rectum together, ...	20	0
Total length of intestinal canal, exclusive of the cæcum, ...	58	6

Our own measurements have unfortunately been mislaid, which is the more to be regretted that the statement of previous observers are very discordant.

Peritoneum.

Hunter has remarked that the lymphatics and lacteals are small. He found no lymphatic glands on the mesentery proper; there were several on the meso-colon, but these were not larger than in man.

"The peritoneum lining the elastic ventral wall of the abdomen in the elephant and rhinoceros is of unusual thickness and strength; the areolar tissue connecting it to adjacent structures presents aponeurotic firmness; the free surface of the serous membrane I found to be white and opaque; it is generally transparent and opaline or colourless."[2] The absence of fat from all parts of the peritoneum has been remarked by more than one dissector of the elephant. In our example the great omentum was quite clear of fat, as indeed were all parts of the body, except the fibrous pads of the soles of the feet and the orbits.

[1] *Comp. Anat. of Vertebrates*, vol. iii. p. 458.

[2] Owen, *Comp. Anat. of Vertebrates*, vol. iii. p. 503.]

Liver.

The liver is divided by the suspensory fissure into two lobes, of which the right is the larger. There is no gall-bladder, but the ductus cholædocus expands in the wall of the duodenum into a sacculated pouch, which receives also the secretion of the pancreas. The termination of the duct projects slightly into the small intestine, and is surrounded by a sphincter.

Pancreas.

The pancreas of the elephant differs little from that of most mammals; it does not reach the spleen.

Spleen.

The spleen is long and flat, broader in the centre than elsewhere, and occupies its usual position.

MALE GENERATIVE ORGANS.

Dr Morrison Watson's account of the male organs of the elephant,[1] evidently founded upon a careful dissection, but neglecting no advantage which is to be derived from the comparison of earlier descriptions, is probably the best accessible, and we may refer the reader to it for particulars of the arrangement.

It will be of interest to give here some passages from a letter of Dr William Ogle, in which are quoted the first extant accounts of the anatomy of the elephant. The description of the generative organs seems to imply actual dissection by some ancient anatomist.

"Aristotle most probably, as I think, never saw an elephant himself, but the following passages from his *Historia Animalium* show that even at that early time some one or other either had or professed to have examined the inside of one.

"II. 17. 'The elephant's intestine is formed of parts so put together as to give the appearance of there being four stomachs. Its viscera resemble those of the hog, but are of course much larger. The liver, for instance, is four times as large as that of an ox. The spleen, however, is of small size, considering the large bulk of the animal.'

"II. 1. 'The penis of the elephant is like that of the horse, but small considering the animal's bulk. The testes are not visible externally, but are placed inside, near the kidneys. The pudendum of

[1] *Journ. of Anat. and Phys.* vol. iii. p. 65 (1872).

the female is placed in the position which in ewes is occupied by the dugs, but for congress is drawn upwards and directed outwards, so as to facilitate the action of the male. It has naturally a wide orifice.' "

FEMALE GENERATIVE ORGANS.

OVARY.

The ovary in our young example was about one-third larger than in the adult human female, deeply corrugated on the surface, and of a flattish oval figure. Many immature Graafian follicles were distinguished.[1]

FALLOPIAN TUBES.

The commencement of each Fallopian tube lies within a somewhat capacious pouch, which holds 3½ ounces of water when distended. The fimbriæ expand over the membranous walls of the pouch, and project as ridges from the inner surface. The outer surface is covered with peritoneum. Scattered muscular fibres (unstriped), together with vessels and nerves, lie in the membrane. The ovary lies, not in the fimbriated pouch itself, which directly communicates with the Fallopian tube, but in a separate compartment, lined with peritoneum, in whose wall the fimbriated pouch may be said to be excavated. A valve or membranous fold separates the two cavities. On the side of this valve, remote from that part of the pouch which ordinarily lodges the ovary, the Fallopian tube may be seen, expanding to its orifice. In the opposite direction it rapidly contracts to a long, narrow, and tortuous canal, which suddenly expands again to an outside diameter of about half an inch. From this point each of the cornua uteri converges towards its fellow, running parallel therewith for the last 3 inches of its course, and opening finally into the common uterus. The total length of each is about 14 inches. A number of uterine glands are visible towards the lower end of the cornua.

UTERUS.

The cornua unite to form a short tube of about an inch in

[1] Mayer describes the outer surface as smooth "and only provided with lobes (Läppchen) at its point of attachment." He says, further, that there are no projecting Graafian follicles.

length and three quarters of an inch in diameter. This leads into a somewhat larger chamber about three inches long, which represents the cervix uteri. The wall of the uterus is provided with circular muscular fibres. Outwardly the uterus is with difficulty distinguished from the vagina, but on opening the tube loose longitudinal folds of the mucous surface are found to converge towards two well-marked (anterior and posterior) internal protuberances, which nearly close the passage from one to the other, forming thus a kind of os uteri.

Dr Watson finds no constriction corresponding to an os uteri in the female of *Hyæna crocuta*, and goes on to say:—"The same remark holds good, so far as I can ascertain, of only one other placental mammal—that is, of the Indian elephant, in the female of which, as Mayer pointed out, the vagina is altogether absent, and the uterus opens directly into the urino-genital canal."[1] Mayer does not actually use this language, for he regards the uro-genital canal as vagina ("die mit der Urethra vereinte Vagina"), but the facts as described by him admit of Dr Watson's interpretation. Whether the uterus is really perfectly continuous with the vagina is another question, and here we must remark that we find much discrepancy between Mayer's account and the actual part which is now before us. Shortly below the union of the Fallopian tubes, there is visible externally a slight constriction. At the same point two considerable and well-marked enlargements project inwards from the internal wall and almost close the passage. Above this point the uterine wall is more distinctly and closely plicate than below. Hence the united Müllerian ducts appear to us to be plainly divisible (above the uro-genital canal) into two parts, which are separated by a constriction and differ in internal structure. The upper part seems to us to represent the uterus, and the lower the vagina, while the internal thickening may well represent an os uteri. It would be interesting to know something of the gravid uterus of the elephant, and in particular to ascertain by direct observation in what part of the united sexual ducts the fœtus is lodged, but we have no observations before us which bear upon this point.

[1] *Proc. Zool. Soc.* 1878, p. 424.

VAGINA.

The next division of the generative canal may be distinguished as the vagina. It is about 9 inches long, and tapers upwards. The walls are almost entirely destitute of muscular fibres. On its inner surface a number of small and irregular rugæ are seen, some of which converge to an indistinct anterior and a posterior raphe.

URO-GENITAL CANAL.

Close to the entrance of the urethra into the generative duct a marked constriction is externally visible, and here, when the peritoneum is removed, the outer surface, which was smooth and membranous in the region of the vagina, becomes strongly marked by circular muscular fibres. On opening the tube a narrow passage serves as the only communication between the proper vagina and the vulva, or uro-genital canal. This passage is divided into lateral halves by a thick rounded cord covered by mucous membrane, which is apparently a hymen.[1]

The uro-genital canal is more than twice as long as the proper vagina, and when freed by dissection and extended, it projects 14 or 15 inches beyond the anus. In the natural (unexcited) state the tube is curved forwards and opens on the under surface of the belly, but by distention of the crura clitoridis it can be so far straightened that the orifice looks almost directly backwards, being then beneath the anus, but separated from it by a considerable interval. Thus the urine is ordinarily discharged downwards and forwards, but sexual congress takes place in something like the position ordinary among quadrupeds.[2]

In the upper half of the uro-genital canal, above the root of the clitoris, its walls are invested by nearly circular muscular fibres, which are less distinct on the side adjacent to the rectum, and are also less developed in the lower part of this space. A strong band of muscular fibres is attached for about 2 inches

[1] It would be well to ascertain, when an opportunity occurs, whether this band is ruptured by copulation or parturition, as the descriptions of Hunter and Mayer indirectly lead us to suppose probable.

[2] Dr Watson informs us that the evidence of eye-witnesses, though not so ample or explicit as might be desired, goes to show that the female rests upon the fore-knees with the hind legs extended in the standing posture.

to the body of the clitoris, near its root, and extends upon the sides of the uro-genital canal. These fibres diverge considerably, the lower ones passing nearly transversely, while the upper ones pass upwards and forwards at an angle of about 45°. They terminate along a defined line on the intestinal side, so that the muscles of opposite sides are separated by a clear membranous space of about 2½ inches. Some of the higher fibres are continued over the side of the rectum, and become continuous with the anterior fibres of the *sphincter ani*, while a number of more scattered fibres proceed from the upper part of the uro-genital canal, and are lost upon the sides of the rectum. The last nine inches of the canal have the walls thin and comparatively membranous, but muscular fibres can be still detected, which are attached to the sides of the clitoris and surround the tube.

When the uro-genital canal is laid open, its inner surface is seen to be lined by a smooth mucous membrane. An interrupted line of dark spots is visible near the external outlet, running about an inch apart from the defined line which marks the junction of the epidermic and epithelial surfaces. Two sinuses (canals of Malpighi?) open on the superior (intestinal) wall of the canal about the middle of its course, and can be traced for about 2 inches upwards. They open towards the outlet of the uro-genital canal. No glandular bodies were discovered in connection with the sinuses. The orifice of the urethra is a simple rounded opening on the side remote from the rectum.[1]

The uro-genital outlet is not situated near the anus, but is ordinarily drawn forward, so as to reach the symphysis pubis. Its sides are very loose and do not appear to be provided with a distinct sphincter. The labia, or loose folds covered with mucous membrane, form a hood or prepuce to the prominent glans clitoridis.

Clitoris.

In our specimen the clitoris measured 14 inches, and the glans projected nearly 2 inches. The two diverging crura

[1] Hunter (*Essays and Observations*, vol. ii. p. 175), says that "at the termination of the proper vagina its cavity contracts at once, almost into a blind end; in the centre of which there are three small openings, neither of them larger than a crow-quill; the two lateral of these lead to two small sacs which pass a little way along the sides of the common vagina."

spring from the rami of the os pubis. Beyond this junction the clitoris is nearly cylindrical. The vessels and large nerve lie on either side, while in the middle line, enclosed in a distinct membranous sheath, is the common tendon of the *retractores clitoridis*. These consist of a pair of small tapering muscles, which unite about 5 inches below their origin in a common tendon. This passes along the dorsum of the clitoris, and is inserted into the glans. The cavernous structure of the crura clitoridis is well marked, and they can be easily inflated. The glans is terminal and semi-globular.

Accessory Reproductive Organs.

The mammæ are pectoral, and two in number. They lie between the fore-legs. The two glands are contiguous, and the nipples are nearly intermediate between the middle line of the thorax and the axilla.

A temporal gland, situated above the zygoma, and half-way between the eye and the ear, may be possibly an accessory reproductive organ. It is flat, and in our example of squarish outline. It lies upon the temporal muscle, from which, however, it is separated by the temporal venous plexus. The excretory duct is short and of very small calibre, opening from the lower end of the gland. In the male and during the rutting season, a copious flow of odorous liquid is said to be discharged from the orifice. Our example was an immature female, but the gland was nevertheless well developed and conspicuous. It measured 3½ inches by 3 inches, and weighed about two ounces.

URINARY ORGANS.

Each kidney showed five lobes in our example, but other dissectors report various numbers, from two to eight or nine. The lobes were essentially distinct, each having its own cortical and medullary substance and a separate calyx, but the external separation was not very marked. Two or three Malpighian pyramids, hardly projecting into the calices, were found in each lobe; on the flattened apex of each the renal tubes were distinguished by the eye. The calices of the three anterior lobes united to form a common canal, which after a course of about

3 inches was joined by a similar tube formed by the union of the two posterior calices. Here the ureter was much dilated; it tapered towards the bladder for the first 4 inches of its course, and then continued with a nearly uniform diameter to near its termination, where it suddenly narrowed. The whole length was 18 inches.

The supra-renal capsules were transversely elongate, tapering to a point on the outer side.

Comparison of different descriptions of the elephant's kidney reveals much discrepancy as to the number and distinctness of the lobes, the number of calices and their mode of entry into the ureter. The unlikeness of Camper's figure to our dissection is extreme.

The bladder presents no remarkable features. The orifices of the ureters were seven-eighths of an inch apart[1] (in our young elephant), and the orifice of the urethra was about two inches distant from them. The ureters lie for about an inch between the coats of the bladder. In the young female the urethra is about an inch long, opening on the front of the uro-genital canal close to the proper vagina.

HEART AND VESSELS.[2]

Heart.

The heart of the elephant has been repeatedly dissected, and may now be treated briefly. For fuller particulars the reader may consult Vulpian and Philipeaux,[3] together with the corrections and additions of Dr Morrison Watson.

The pericardium is pointed forwards, where it is united to the base of the heart. Two fibrous cords pass from the back of the pericardium to the tendinous centre of the diaphragm. Dr

[1] In Dr Watson's example the two ureters were separated by a distance of 3½ inches, and lay for 2¾ inches in the wall of the bladder.

[2] It was our first intention (this *Journal*, vol. xii. p. 264) to omit the heart, lungs, and liver, seeing that Messrs Vulpian and Philipeaux have described them so minutely, but on comparing their account with our dissection, and with Dr Watson's notes, we find not a few discrepancies of greater or less importance. A short notice of these viscera is therefore included in the present memoir.

[3] *Ann. Sci. Nat. Zool.* 4e sér. tom. v. p. 183 (1856).

Watson finds them specially connected with the anterior of two plates of yellow elastic tissue which cover the two surfaces of the muscular portion of the diaphragm. He observes further "that the pericardiac band of the right side was entirely composed of that peculiar form of yellow elastic tissue which, so far as I am aware, has only once before been described, and that in the ligamentum nuchæ of the giraffe by Mr Quekett. In the left band, as well as in the plate into which the bands expanded, the elastic tissue presented the usual appearance." Vulpian and Philipeaux speak of the fibrous band as single.

The base of the heart is depressed forward, and the interventricular septum is nearly vertical and longitudinal. In the following remarks we shall use terms of direction and position with reference to the natural state of the parts. The base is understood to be anterior, the apex posterior, and the right auricle dorsal or superior.

With respect to the general form of the heart, the separation of the apices of the ventricles is the most important feature.[1] Vulpian and Philipeaux say: "Il n'y a pas de sillon inférieur inter-ventriculaire nettement dessiné. Il y a, au contraire, un sillon supérieur très profond, qui, du milieu de la base du cœur, se porte au voisinage de la pointe." In our example the case was almost reversed; the superior groove was shallow and unimportant, whereas the apical interventricular groove was deep and conspicuous. The right side of the heart is, so to speak, rotated upon the centre of the left; the right auricle being thrown to the dorsal surface of the heart, while the principal axis of the right side, passing directly through the auriculo-ventricular orifice, is inclined upwards, instead of lying nearly horizontal, as does that of the left side in the animal as it stands. The inferior face (anterior of man) gives no indication of this tilting of the right side, except that the right auricle is displaced; the two ventricles meet along a straight line and divide the lower surface nearly equally. Vulpian and Philipeaux found much fat at the base and on the front of the ventricles—the only instance we can recollect in which any considerable quantity of

[1] In some Cetacea the apex of the heart is indented, while in Sirenia, particularly in the dugong, the separation of the ventricles is even more marked than in the elephant.

this substance has been met with in any part of the elephant The heart dissected by us was perfectly destitute of fat.

Right Auricle.—The walls are thin, but strengthened by pectinated muscles above, as well as in the appendix, which is hardly separable from the general cavity. Vulpian and Philipeaux describe the wall as areolated towards the venæ cavæ, but this was not the case in our example, except behind the left anterior cava. Two anterior venæ cavæ (right and left) enter, one towards the base, the other towards the apical end, and a posterior vena cava on the dorsal and external side, somewhat in front of the left anterior cava. A sigmoid valve passes from the external side of the right anterior cava, adjacent to the appendix, curves round the ventral side of the orifice, and is then continued as a long membranous ridge of slight projection to the basal or anterior side of the posterior cava; it then crosses that opening on its ventral margin, becoming somewhat more prominent, and serving as a proper valve to the posterior cava; finally, it gradually disappears along the base of attachment of the Eustachian valve. This agrees tolerably well with the description of Vulpian and Philipeaux; and with Dr Watson's figure, though in the text of his description he says that the valve passed round the *upper* margin of the right anterior cava. A large Eustachian valve separates the posterior from the left anterior cava. The great coronary vein opens into the left anterior cava under cover of a pectinated muscle.

The two superior venæ cavæ in the elephant, as in monotremata, marsupials, many rodents, the hedgehog, and the bat, and by a rare deviation from the ordinary rule in the human subject also, are explicable as a retention of an embryonic structure very general in vertebrates. At first the blood is returned to the heart by an anterior (jugular) and a posterior (cardinal) pair of venous trunks, as well as by a median posterior, which persists and constitutes the inferior cava. The cardinal and jugular veins of each side unite to form a precaval or canal of Cuvier, and the two precavals are primitively united into a common trunk which enters the undivided auricle. The common precaval trunk ultimately forms part of the right auricle into which the two precavals then open separately, forming the right and left superior (or anterior) venæ cavæ. A transverse connection is next established between the jugular veins; the left jugular, below the transverse branch, and the left precaval contract and become obliterated; while the enlarged transverse branch becomes the left innominate vein, and the lower part of the right jugular together with the

right precaval forms the single superior (or anterior) vena cava of the higher mammalia. The coronary sinus is, according to Mr Marshall, the only part of the left anterior cava which in these mammals remains pervious. (See Rathke, *Meckel's Archiv.* 1830, p. 63; and *Ueber den Bau und die Entwickelung des Venensystems der Wirbelthiere*, Königsberg, 1838; Bardeleben, *Müller's Archiv.* 1848; Marshall, *Phil. Trans.* 1850, part i.; and Owen, *Anatomy of Vertebrates*, vol. iii. p. 551.)

Right Ventricle.—The "incomplete septum" of Vulpian and Philipeaux seems to consist merely of the more or less united fleshy columns. In our example these differ considerably from the description of the authors just named. Four or five are attached, low down, to the external wall; three or four others, less distinct, from the ventricular wall to the interventricular septum. All the very numerous tendinous cords spring from fleshy columns, though these have not on the inner side of the ventricle any considerable free extent. No corpora Arantii are present on the semilunar valves of the pulmonary artery. The wall of the ventricle is cavernous towards the tricuspid valve, and also along a line leading from the apex to the orifice of the pulmonary artery, close to the ventral border of the interventricular septum. The tricuspid valve may have one or two (in our example two) small additional cusps.

Left Auricle.—The entry of the pulmonary veins seems to vary. Vulpian and Philipeaux found two openings into the auricle—a small internal and a large external, which latter received three of the pulmonary veins. Dr Watson describes four separate openings. In our dissection there was a large central orifice and a smaller one on each side—one internal and the other external; but the external vein was not altogether clear of the central one. A thin ridge upon the internal surface of the auricle separates the central from the internal orifice. The veins enter a thin and membranous sinus, which is slightly separated from the rest of the auricle by a prominent fleshy ridge. Part of the edge of this ridge forms the "valvular structure" noted by Dr Watson. The wall of the left auricle is strengthened, especially on the anterior and external sides, by numerous trabeculæ. The fossa ovalis is distinguishable only by a slight transparency.

Left Ventricle.—The mitral valve forms a continuous mem-

branous ring, but indications of a separation into internal and external cusps are visible. Vulpian and Philipeaux found only two fleshy columns in the left ventricle—one above and the other below. We can distinguish four or more, all nearly on the same level, but divisible into an internal and external set. The aortic valves are continuous with the inner mitral.

Coronary Vessels.—Camper was probably mistaken in saying that there is only one coronary artery. Like several previous observers, we find two. The great coronary vein opens into the left anterior cava.

Pulmonary Artery.—Three dilatations, corresponding to the sinuses of Valsalva, are distinctly visible externally. The artery passes forwards, upwards, and to the left, curving round the aorta and dividing in the concavity of the aortic arch into two branches, one to each lung. The nearly obliterated ductus arteriosus passes obliquely from right to left, from the pulmonary artery shortly before it divides to the aorta, which it enters immediately to the left of the left subclavian artery.

Aorta.—The arch of the aorta gives off a very short innominate trunk, which subdivides into the right subclavian and the two carotids, and secondly, a left subclavian.[1] An *arteria thyroidea ima* proceeds from the point of separation of the two carotids.

We have traced the arteries throughout the body, but the details of distribution offer few significant features.

Anterior Venæ Cavæ.—Dr Watson observes that "each was formed by the junction of *three* large trunks a short distance in front of the arch of the subclavian artery. Of these, one came from the outside, a second came from the direction of the middle line, whilst an intermediate one passed directly backwards. The vena cava of each side, thus formed, passed directly backwards, receiving in its course several smaller veins, one of which was the trunk formed by the union of the companion veins of the mammary artery, and finally opened into the right auricle. In addition to these, the right anterior cava received the azygos vein immediately before piercing the pericardium. There was

[1] Cuvier and Mayer seem to have found three trunks, viz., right subclavian, carotid, and left subclavian. Hunter, Owen, Vulpian and Philipeaux, and Watson agree with the statement in the text.

no trace of a small or left azygos vein: the posterior cava, immediately after piercing the diaphragm, opened into the auricle."

VEINS AND VENOUS PLEXUSES.

The most striking peculiarity of the veins lies in the plexuses and free anastomoses which occur in nearly all sheltered parts of the body. We find extensive plexuses in the superficial and deep temporal, pharyngeal, pectoral, anterior and internal femoral, popliteal, axillary, and brachial regions, besides less important communications elsewhere. The veins are in general large and capacious. In some cases, at least, valves are wanting in the plexuses, but we were unable to test the freedom of communication in different directions by a general venous injection.

Superficial Temporal Plexus.—This lies above the zygoma and behind the eye, beneath the temporal gland and superficial to the temporal muscle. Its communications are with the temporal vein by means of a superficial branch which crosses the posterior end of the zygoma, with the internal maxillary and facial veins, and with the deep temporal plexus. The temporal artery crosses the zygoma immediately behind the vein noticed above, and gives branches, which do not inosculate, to the area of the venous plexus.[1]

Deep Temporal Plexus.—On reflecting the *temporalis* muscle, a large and intricate venous plexus is seen. The largest of the contributory veins cross the temporal fossa longitudinally under cover of the zygoma, and communicate in front with the interorbital veins. Two considerable branches pass in front of the neck of the lower jaw to communicate with the superficial temporal plexus, as also do some smaller branches at the anterior border of the *temporalis.*

Pterygoid Plexuses.—There is a complicated network of veins overlying the *pterygoideus externus,* and communicating (1) with the longitudinal veins of the deep temporal plexus; (2) with the internal maxillary vein; and (3) with the superficial temporal

[1] Neugebaur has described a temporal venous plexus in the goose (*Nova Acta,* vol. lxxi. p. 521. 1845). In Froriep's *Notizen,* Oct. 1832, p. 39, Otto has described the superficial temporal plexus of the elephant as *arterial,* an error corrected by Dr Watson. The same mistake is repeated in Owen's *Anatomy of Vertebrates,* vol. iii. p. 548.

plexus, by means of the veins passing in front of the neck of the lower jaw.

When the *pterygoideus externus* is reflected, a free anastomosis of large veins is found, which receives branches from (1) superficial temporal; (2) deep temporal; (3) superficial pterygoid plexuses; (4) inferior dental veins; (5) venæ comites of meningeal artery. The plexus discharges into the internal jugular vein by four large trunks.

Pharyngeal Plexus.—This lies at the back of the mouth, and has been noticed in the description of the pharynx. On each side it receives muscular and vertebral veins; the internal jugular, with lingual, muscular, and facial branches; the internal maxillary; and a descending palatine vein. A single transverse branch connects the plexuses of the two sides.

Pectoral Plexus.—Beneath the *pectoralis* is a plexus of great extent and intricate arrangement, which effects communications with the intercostal, internal jugular, axillary, and internal mammary veins.

These particulars will probably suffice respecting vascular arrangements whose physiological interpretation is as yet so obscure. The plexuses of the extremities lie usually in the hollows of joints, and are both numerous, intricate, and capacious. Our notes and drawings preserve many details which it is not thought needful to describe in print.

Van der Kolk and Vrolik,[1] Hyrtl,[2] and others[3] have collected many examples of vascular plexuses in vertebrate animals, and have suggested several possible theories of their physiological effect. It seems necessary to distinguish and classify before any explanation is attempted, for no single explanation can possibly apply to all the recorded cases. Arterial and venous plexuses must be carefully separated, though this has not always been attended to. With respect to the arrangement of their component vessels, some plexuses arise by the breaking up of a trunk into many small branches, which subsequently reunite, and may be compared to a rope untwisted in the middle (*funi-*

[1] "Recherches sur les plexus vasculaires chez différents animaux," Zool. Soc. of Amsterdam, transl. in *Ann. Sci. Nat. Zool.* 4e sér. tom. v. p. 111 (1856).

[2] "Neue Wundernetze und Geflechte bei Vögeln und Säugethieren," *Kais. Akad. d. Wiss. Math. naturw.* Bd. xxii. (1863). Also reprinted separately, 1864.

[3] Müller, Von Baer, Carlisle, Breschet, Milne Edwards, Turner, Murie, &c.

form plexuses). Others form a network of communication between different vessels (*retiform* plexuses). Others, again, are due to the sudden breaking-up of an artery into many small branches, which may anastomose, but do not reunite; or to the entry of many small veins into a common trunk at or near the same place (*distributive* plexuses).

Such plexuses as we have seen in the elephant are all venous and retiform. We have no confident opinion respecting their physiological meaning. It may be worth while to remark that they are so extensive as to constitute in the aggregate a not inconsiderable reservoir of blood, which may remain nearly motionless, or move sluggishly when the animal is at rest, but must be impelled towards the heart by energetic contractions of the adjacent muscles. The small development of the lymphatic system is also an important, and not impossibly a related fact. The lymphatic glands are few and small, and the thoracic duct was not, in our example, materially larger than in an adult man. That the venous blood lodged in these many plexuses may have an absorbent office is a possible view, but one upon which we do not venture to lay emphasis.

RESPIRATORY SYSTEM.

Larynx.

The thyroid consists of two rhomboidal alæ, whose superior and inferior borders respectively converge forwards to the middle line at an obtuse angle. They are continuous in front for the upper half of their depth, and strongly connected by yellow elastic tissue in the lower half. The cornua project very slightly. To the postero-superior angle the cartilaginous tip of the thyro-hyal is articulated by a capsule lined with synovial membrane; the postero-inferior angle is similarly connected with the prominent lateral facet of the cricoid cartilage. The cricoid and arytænoid cartilages differ in no material respect from the same parts in man. Professor Owen observes that "the cricoid extends posteriorly over the first three tracheal rings."[1] This is not the case; the three upper rings of the trachea are obliquely

[1] *Anat. of Vertebrates*, vol. iii. p. 591.

cut off behind, and their edges are connected with the lower border of the cricoid. The epiglottis is very thin and flexible.

The *crico-thyroidei* are closely united in the middle line (C. and L.—261, fig. 2, z^1). *Crico-arytænoideus posticus* passes vertically to the base of the arytænoid cartilage, and the muscles of opposite sides blend. There is no *cerato-cricoideus*. *Arytænoideus* consists of a single set of fibres, which converge from each side to a transverse median tendon. The upper fibres are continuous with *thyro-arytænoideus*, so that the two muscles form a complete ring round the larynx. *Crico-arytænoideus* springs from the upper half and edge of the side of the cricoid cartilage; it is almost continuous with *thyro-arytænoideus* towards its insertion. *Thyro-arytænoideus* arises from the whole depth of the thyroid cartilage in the middle line, including the elastic tissue which closes the inferior vertical notch. The fibres pass downwards and backwards, to be inserted into the outer and posterior surfaces of the arytænoid cartilages. The muscle is continuous behind with the upper fibres of *arytænoideus*. No depressor of the epiglottis was made out. *Hyo-epiglottideus* (elevator of the epiglottis) is a strong muscle arising close to its fellow, from which it is separated by a septum of yellow elastic tissue. It springs from the basi-hyoid close to the middle line, and passes directly backwards to the anterior surface of the epiglottis, having a length of about three inches. The two muscles underlie the thyro-hyoid membrane and support this part of the floor of the pharyngeal pouch. Camper's drawing (pl. xii. fig. 4) is fairly correct, except that he does not indicate any separation of the muscles of opposite sides.

The upper or false vocal cord is rounded and hardly apparent except behind. The lower is straight and well-defined, with a sharp vibratile edge. A small laryngeal pouch leads backwards from the ventricle, and extends for a short distance under cover of the antero-external border of the arytænoid cartilage.

The superior laryngeal nerve pierces the anterior border of the thyroid cartilage near its centre.

Below the arytænoid cartilages and vocal cords the internal surface of the larynx is covered with longitudinally wrinkled yellow elastic tissue similar to that of the trachea. The mucous membrane above the vocal cords resembles that of the pharynx.

TRACHEA.

The trachea consists of about thirty rings. These are incomplete behind, and occasionally subdivided, the joints being enclosed in synovial capsules. The tube is lined by yellow elastic tissue thrown into firm and very narrow longitudinal folds. The space between the ends of the rings behind is occupied by two distinct layers of unstriped muscle, the outer layer being transverse and the inner vertical in the central part, but radiating outwards laterally.

BRONCHI.

"The right bronchus consisted of eight, the left of six rings. In addition to these, however, there were several cartilaginous nodules of small size representing rudimentary rings. No accessory bronchus, such as is so common among the ruminants, was met with, the azygos lobe of the right lung receiving its air-tube from the right bronchus after it had entered the substance of the lung."—(*Watson.*)

LUNGS.

The shape of the lungs is adapted to the deep and narrow thorax; the whole of the ventral surface is in contact with the diaphragm, which extends forwards to the second or third rib. The visceral and parietal layers of the pleura are closely connected together by matted elastic tissue, while the pleural sac is at the same time pretty generally adherent to the thoracic wall on the one hand and to the surface of the lungs on the other. The right lung, according to Vulpian and Philipeaux, has a small upper lobe, a triangular internal lobe, which rises towards the trachea, and a very considerable third lobe. Dr Watson found only two lobes, of which the smaller lay on the left side and projected transversely from the lung immediately below the hilum. In our example the arrangement was nearly the same. The left lung is undivided. The lobules are very easily separable. Dr Watson observes that the bronchi branch irregularly, and that upon entering the lung they immediately lose the cartilaginous laminæ. This was the case in our subject also.

NERVOUS SYSTEM.

We are not able to give any useful information respecting the nervous system of the elephant. The brain was not removed until eight months after death, when its internal structure was much broken down. We have traced the chief nerves, but find no peculiarities sufficiently remarkable to justify a minute description.[1]

ORGANS OF SPECIAL SENSE.

EYE.

Mayer describes a special depressor of the lower eyelid, and Dr Watson confirms the statement. It arises with the *recti* and *obliqui* from the bony canal posterior to the orbit, and passes forwards beneath the eyeball to be inserted into the cartilage of the lower lid. Dr Watson notices also "a very extensive and well-developed periosteal muscle," which "corresponds exactly in position to the similar muscle in the sheep and deer."[2] The muscles which pass from the upper and lower eyelids to be inserted into the third eyelid are not, according to Dr Watson, distinct muscles at all, but fibres of the *orbicularis palpebrarum*.

Camper, Harrison, and Watson agree in stating that no true lachrymal apparatus is present. The Harderian gland lies between the inner wall of the orbit and the *rectus internus;* its excretory duct opens on the surface of the third eyelid.

EAR.

The membrana tympani is of oval form, and looks downwards, outwards, and a little forwards. The malleus is attached above the centre to the apex of the shallow funnel, which, as in other mammalia, projects inwards from the tympanic membrane. The apex of the funnel is directed upwards and forwards. In our young example the long diameter of the membrane was $\frac{7}{8}$ inch, and the short diameter $\frac{1}{8}$ inch less. Sir Everard Home

[1] For the relative sizes of the cranial nerves, Dr Harrison's description may be consulted. Quoted (with figure) in Sir J. Emerson Tennent's *Natural History of Ceylon*, p. 95.

[2] Described by Professor Turner in the *Proc. Royal Phys. Soc.* Edinburgh, Dec. 19, 1861, and *Nat. Hist. Review*, Jan. 1862.

gives $\frac{17}{20}$ inch as one dimension, and rather more than an inch as the other.[1] This was probably from an adult animal. The middle layer contains the usual radiating and circular fibres. No peculiarity of importance was observed with respect to the ossicles.

NOSE.

The cartilaginous nasal septum continues forwards the plane of the vomer and of the perpendicular plate of the ethmoid. It ends in front by a tapering projection which extends in advance of the bony nares, and supports the alinasal cartilages. The cartilage of the septum is not prolonged into the fibrous and muscular septum of the proboscis. Its upper edge gives origin to a set of longitudinal muscular fibres, which increase in number below, and ultimately blend with the under surface of *levator proboscidis*. The same edge gives off on each side a narrow lateral process, continuous along the whole length of the septum, and to these processes the alinasal cartilages are attached in front of the bony nares by a simple hinge-joint, without synovial capsule. In our young example each alinasal cartilage measures four inches in length and less than one inch in width; it has a slight curvature forwards and outwards. Its external margin is connected with the bony nares beneath *levator proboscidis* by a thin, tough, and extensive sheet of fibrous membrane, which can be traced downwards into the lining of the air-tubes of the proboscis. The membrane is capable of distension, and forms a kind of pouch, which greatly enlarges the capacity of the nares at this point. Transverse muscular fibres, continuing the series of the radiating fibres of the proboscis, connect the sides and under surface of this pouch with the margin of the bony nares. Another set of transverse fibres (*dilator naris*), extending across the alinasal cartilage and taking origin from it, passes to the adjacent border of the pouch, leaving a clear space about an inch in width between them and the lower transverse fibres. This upper set (*dilator naris*) would, when in action, tend to raise the free or external edge of alinasal cartilage, and thus increase the capacity of the pouch, while the lower transverse fibres would assist them to enlarge the pouch by drawing its sides outwards. The alinasal pouch

[1] *Phil. Trans.* for 1800, p. 4.

is the only considerable chamber in the nose or trunk of the elephant; it may serve an important purpose in the storage of liquid. Behind the anterior bony nares we find a second lateral (aliseptal) cartilage. It is not perfectly continuous either with the nasal septum or the alinasal cartilage. It is connected with the former by a fibrous hinge-joint; with the latter by a strong elastic sheet, in which are a number of muscular fibres, which take origin from the upper border of the bony nares, and converge towards the fore end of the aliseptal cartilage. The position and form of this cartilage are those of a turbinated bone, but it is wholly unossified; its size is small in comparison with the relative development of the turbinated bones in most mammals. Its chief extension is in the direction of the nasal passage, and this dimension is about four inches in our specimen; the greatest vertical depth is two inches. The anterior half of the cartilage falls away outwards from the plane of the posterior half, so as to give rise to a decided step in the middle of the length. The general direction of the cartilage is vertical, but somewhat irregular, and the lower edge is rather nearer to the median plane (especially in its posterior half) than the upper. This aliseptal cartilage forms part of the outer wall of the nasal passage, as well as the inner wall of a transversely contracted channel which leads from the nasal meatus to a large frontal sinus. The muscular fibres attached to the fore edge of the aliseptal cartilage, which are continuous with the lower set of the transverse fibres of the alinasal pouch, when they contract, draw the cartilage towards the bony or outermost wall of the nasal chamber, and very effectually close the entrance into the air-sinus. The lower border of the cartilage, for somewhat more than the anterior half of its extent, is connected with the wall of the nasal chamber by a strong band of yellow elastic tissue, which forms part of the dividing septum between the proper respiratory passage and the entrance to the frontal air-sinus; it serves to antagonise the muscular fibres which close the valve. The posterior extremity of the cartilage is connected to the lateral wall by a mass of fibrous and mucous tissue, which forms the anterior boundary of the special respiratory chamber, and separates this from the channel leading to the frontal sinus. The aliethmoidal volutes are disposed in

about seven laminæ, which gradually diminish in size backwards, and closely resemble the bony framework of the olfactory organ in the horse. Behind this point the nasal passage lies between the hard palate and the spheno-palatine surface. Its vertical extent in our young example is nearly three inches, but the transverse width is extremely small, and hence the nasal passages seen from behind present the appearance of greatly elongated vertical slits. (See p. 20.)

Dr Watson believes that the valve-like aliseptal cartilage is adapted to obstruct the flow of water into the air-sinuses of the skull during its passage along the narial tubes. We are disposed to question the normal passage of water along this highly sensitive tract. Examination of the parts discovers no valve or other provision for preventing water flowing from behind forwards[1] from gaining free entrance into the olfactory recesses. Moreover, the only important receptacle above the stomach is constituted by the pouch adjacent to the alinasal cartilage. We are inclined to suppose that the water lodged here (if, as we see no reason to doubt, the pouch in question actually serves as a receptacle for liquid) is pumped up through the proboscis, and never passes backwards beyond the anterior bony nares. The water which, according to the testimony of many observers, is regurgitated from the stomach, would, we imagine, be withdrawn exclusively by the tip of the proboscis inserted through the mouth into the pharyngeal pouch.

CONCLUDING REMARKS.

It may be worth while to direct the attention of future dissectors to certain points, which have been passed over or inadequately treated by us. Most of these are superficial or easily made out, and it is to be hoped that the first opportunity may be seized of correcting our notes.

1. The cutaneous muscles should be redissected and more fully described.

2. The sterno-humeral and superficial cervical muscles (*pectoralis, masto-humeralis, sterno-maxillaris, sterno-mastoideus*) were insufficiently noted by us, and in the first hasty examination of the thorax, made before the possibility of a complete dissection

[1] See the quotation from Dr Watson's memoir on p. 24.

was entertained, these muscles were mutilated beyond recovery. We have attempted to piece together and interpret the remaining shreds of muscle, but the results are not altogether trustworthy.

3. The large intestine should be studied microscopically while quite fresh.

4. The brain should be removed immediately after death, and minutely investigated. The parts liable to be injured in the process of extraction are now well known.

The difficulties attending the anatomical examination of a single example of a very large animal must be our excuse for many shortcomings. If we shall be found to have aided the next observer as much as Camper, Cuvier and Watson have aided us, we shall at least have repaid our debt. We do not doubt that much, very much, remains to be done before the structure of this single species is adequately made known. Minute and accurate knowledge of the anatomy of the elephant will be found of special value, and competent anatomists are happily not so few that we need grudge the time and labour which minute and accurate knowledge is sure to cost.

EXPLANATION OF PLATES.

Plate II.

Fig. 1. Inner side of right fore-limb. *h.*, Humerus; *co.*, coracoid process; *ol.*, olecranon; *r.*, radius; *sm.*, *serratus magnus; sc.*, *subscapularis; sp.*, *supra-spinatus; tm.*, *teres major; pct.*, *pectoralis; bi.*, *biceps; cb.*, *coraco-brachialis; tr.*, *triceps; de.*, *dorso-epitrochlearis; ba.*, *brachialis anticus; ecr.*, *extensor carpi radialis longior; ep.*, *extensor proprius pollicis; fcr.*, *flexor carpi radialis; pl.*, *palmaris; fld.*, *flexor longus digitorum; pr.*, *pronator radii teres; br.*, brachial artery.

Fig. 2. Flexor side of left fore-arm. *u.*, Ulna; *el.*, elastic ligament; *ecu.*, *extensor carpi ulnaris; fcu.*, *flexor carpi ulnaris;*[1] *an.*, *anconæus; m.*, see vol. xii. p. 271, line 5; *fp.*, *flexor longus pollicis; fbd.*, *flexor brevis digitorum; amd.*, *abductor minimi digiti; emd.*, *extensor minimi digiti; ra.*, radial artery; *un.*, ulnar nerve; *mn.*, median nerve. Other references as in fig. 1.

*** Fig. 2 is drawn on a larger scale than fig. 1.

[1] This should pass in front of *flexor longus digitorum*, to be inserted into the pisiform bone at ×.

Plate III.

Fig. 1. Dissection of the root of the proboscis. Side view. *lp.*, *levator proboscidis* (reflected); *dn.*, *dilator narium;* *an.*, alinasal cartilage; *tf.*, transverse muscular fibres of alinasal pouch.

Fig. 2. Front view.

Plate IV.

Section through nasal passages, pharynx, and larynx. *fs.*, Frontal sinus; *cc.*, cranial cavity; *e.*, Eustachian tube; *ph.p.*, pharyngeal pouch; *jc.*, Jacobson's canal; *bs.*, basi-sphenoid; *mx.*, maxilla; *pmx.*, premaxilla; *mn.*, mandible; *hy.*, hyoid; *an.*, alinasal cartilage; *as.*, aliseptal cartilage; *ae.*, aliethmoidal volutes; *th.*, thyroid cartilage; *cr.*, cricoid cartilage; *cp.*, constrictor pharyngis; *s.*, hind edge of nasal septum.

*** The proportions, especially of the bony parts, will be found to differ from those of the adult elephant.

Plate V.

Fig. 1. Uro-genital organs (female). General view. *sr.*, supra-renal capsule; *k.*, kidney; *b.*, bladder; *o.*, ovary; *u.*, uterus; *v.*, vagina; *ug.*, uro-genital canal; *cl.*, clitoris; *r.*, rectum.

Fig. 2. Ovary and commencement of Fallopian tube. *o.*, ovary.

Fig. 3. Commencement of uro-genital canal (laid open). *h.*, hymen?

A THEORY OF THE HOMOLOGY OF THE SUPRARENALS, BASED ON OBSERVATIONS. By C. CREIGHTON, M.D., *Demonstrator of Anatomy in the University of Cambridge.* (PLATES VI. and VII.)

UNDER the title "Points of Resemblance between the Suprarenal Bodies of the Horse and Dog, and certain Occasional Structures in the Ovary," I communicated to the Royal Society in October last a series of observations, illustrated by drawings, tending to show that the peculiar cortical structures in the suprarenals of at least two mammalian species afford a valuable clue to the nature of the suprarenals in general. An abstract of my communication was published in the Society's *Proceedings* for 6th December 1877. I take the present opportunity of making public the drawings that accompanied my original paper (with four small additions), inasmuch as they are indispensable to a correct understanding and estimate of the facts that I bring forward and associate; and, in preparing another manuscript for publication, I use the occasion to alter somewhat the order of treatment, to introduce some new observations, and to state more emphatically the conclusions that my investigation points to. A considerable part of the inquiry deals with new facts, which have a certain value and interest independent of the theory that they are taken to support; and, for convenience of reference to them, I have divided the paper into sections, placing first the section which is most deserving of notice in that respect.

1. *What becomes of Graafian Follicles within which the Ovum has decayed?* (*Figs.* 1–3, *Plate* VI.)

The ovary, as is well known, is furnished with ova greatly in excess of the number that will ever be ripened or extruded. That is especially the case in such mammals as the dog and cat in which the cortical zone of the ovary is crowded with unripe follicles even to old age; in the human subject and in the larger mammals generally the Graafian follicles occur at wider

intervals.[1] It is chiefly to the ovary of the bitch, and so far also to that of the cat, that the following account applies. The bitch affords unequalled opportunities of studying the fate of Graafian follicles that have aborted or become obsolete, from the fact that towards old age there is a large residuum of follicles, in various stages of ripeness, which, if one may so speak, do not have the chance of discharging their ova at the sexual periods, and which are found, at numerous points throughout the organ, undergoing the process of retrogression or abortion that is now to be described.

Although the retrogression of Graafian follicles is without doubt most frequent towards old age, the occurrence has been described for the earliest periods. Pflüger has described for the cat only a few months after birth certain appearances pointing to a "fatty" degeneration and resolution of unripe follicles.[2] Henle also mentions the occurrence of collapsed follicles in the new-born human fœtus.[3] Waldeyer observes that at the age of 2½, the human ovary is found to contain Graafian follicles almost ripe, if their expansion be a criterion of ripeness, and he concludes that many such follicles necessarily abort.[4] The same author quotes the authority of Reinhardt, Grohe, and Luschka, to the effect that in the human ovary before puberty there occur numerous folded homogeneous membranes, which enclose granular and fibrous contents, and can hardly be taken for anything but the remains of aborted follicles. Again, in the human ovary in old age, Waldeyer found numerous round bodies which appeared to occur uniformly at that time of life throughout the whole cortical or follicular zone. Their size varied from that of an ordinary blood-corpuscle to that of a pavement-epithelial cell; and the author was inclined to regard them as remains of the atrophied contents of follicles, *i.e.*, of the follicular epithelium. In the ovary of the bitch, to which the present account chiefly relates, Waldeyer found round or oval membranes, thick, glassy, and structureless, sometimes folded; they contained granular detritus or spheres of colloid substances, and they appeared to be the remains of ova from follicles that had aborted. Also in the cat, Waldeyer often found aborted follicles, as well

[1] Waldeyer, article "Eierstock," in *Handbuch der Lehre von den Geweben*, p. 550.

[2] A somewhat different kind of obsolescence, which may turn out to be the more important for this theory, is referred to by Waldeyer. In describing the tubular ingrowths from the germinal epithelium, which afterwards form the Graafian follicles, he describes certain of these processes in the three months' puppy which seemed never to develop ova within them. These cortical structures simply remained as solid cylinders. They grew out of the germinal epithelium at a relatively late period, and they remained as "residues" from an earlier stage of development (*Eierstock und Ei*, p. 31).

[3] *Handbuch der Anatomie*, vol. ii. p. 509.

[4] *Eierstock und Ei*, p. 30.

as collapsed ova, with the zona pellucida thrown into folds; the latter sometimes occurred within follicles that were tolerably well preserved. The nearest approach to the appearances that I am about to describe, is stated by Waldeyer for the ovary of the cow. Among the older follicles there occurred not seldom aborted follicles; at least so he regarded certain structures which were abnormally elongated and flattened, and within whose limiting membrane the ordinary cells of the granulosa were replaced by a dense heap of colloid-like bodies. The elongation and flattening of the belt of follicular epithelium is suggestive of the appearances to be described in the bitch. There remain to be mentioned certain observations of His for the ovary of the cow. The degeneration of follicles was often observed. In some cases, the cells of the follicular epithelium were still preserved in a somewhat granular condition, and directly surrounded by the stroma; at the summit of the follicular cavity there was an irregular heap of granular substance, which was perhaps the remains of the discus and the ovum. Some of these altered follicles lay in the neighbourhood of a fresh corpus luteum, and it was not improbable that the growth of the latter had caused the atrophy of a number of the younger follicles near it, by encroaching upon them.[1]

The observations quoted above are not put forward by their authors as altogether free from ambiguity; but the quotations will at least serve to show that the abortion of large numbers of the Graafian follicles has been freely invoked as an explanation of doubtful appearances. I hope in the following description, and with the help of the accompanying drawings, to establish not only the fact of a regular obsolescence in many of the ovarian follicles of the bitch, but also some of the more particular details of that regressive process. The first case in which I found the appearances in question has afforded the greatest variety of obsolete forms, as well as the greatest definiteness; but the ovaries of bitches that I collected immediately thereafter showed enough of the same appearances to satisfy me that their occurrence was quite uniform in that animal at a tolerably advanced age. In the first case, from which most of the illustrations are taken, the animal was old, and the appearances so abundant as at once to arrest the attention. In fig. 1 several of these appearances are given as drawn under a low power. As the interest of the following description centres entirely in the fate of the follicular epithelium, and not in that of the ovum, the fate of the latter may be briefly disposed of at the outset.

[1] "Beobachtungen über den Bau des Säugethier Eierstockes," *Archiv f. Mikros. Anat.* vol. i. p. 193.

The appearances already quoted from Waldeyer may be readily verified in any old ovary of the bitch. The substance of the ovum, including vitellus, germinal vesicle, and spot, disappears, and the zona or vitelline membrane is found more or less empty and collapsed, as a strong, thick-walled vesiole, of homogeneous structure, yellowish colour, and either ovoid in shape or somewhat folded. This tough membrane evidently resists the influences that cause the vitellus and germinal vesicle to disappear, and it is difficult to discover what eventually becomes of it. At all events, in later stages of obsolescence of the Graafian follicle, it is no longer to be seen, and the place of the follicle is marked only by the persisting belt of follicular epithelium. The fate of the enclosing zone of epithelium is in marked contrast to that of the ovum within it; in proportion as the latter shrivels and collapses, the former assumes certain determinate and fixed characters, by which it may be always easily recognised in the midst of the ovarian stroma. The follicles drawn in fig. 1 illustrate various stages in the process of obsolescence. The follicle A exemplifies one of the most fundamental changes. The ovum is wanting in the centre, and the zone of follicular epithelium persists on one side; the point that it is of importance to observe is the form of the epithelial cells.

The follicular epithelium does not, in the earlier periods of life, present the usual characters of an epithelium; the cells are round and almost nuclear, or without cell substance. Under ordinary methods of preparation, and under a moderate magnifying power, they look like naked nuclei, just as the lymphoid cells of a lymphatic gland do under the same circumstances. As the follicle becomes riper the epithelium becomes more cylindrical; it is at the two poles of the nucleus, and not uniformly all round, that the protoplasm collects. This elongation of the epithelium, which is never very pronounced in the follicle destined to extrude its ovum in the ordinary course, becomes quite obvious where the ovum decays within the cavity. The cells are then seen (as in A, fig. 1) to be greatly elongated, cylindrical cells. In B and C the elongation of the epithelium, and the corresponding shrivelling of the ovum, are seen together; at *a*, in the centre of each follicle, is the thick, structureless zona of the ovum, which appears to be as if compressed or encroached upon

by the lengthening radial cells of the follicular epithelium. At the same time, the ends of the cylindrical cells that abut upon the zona appear to have acquired a common bond of union, like a basement membrane. At D is represented a belt of follicular epithelium, broken at the upper side, and without any traces of the ovum within it. The follicle E exemplifies perhaps the most common appearance of the belt of epithelium surviving after the abortion and disappearance of the ovum; the originally circular belt (in section) has become almost straight, and the shrivelled zona of the ovum lies towards its under surface, and almost clear of it. The different forms of the belt of follicular epithelium depend partly on the plane of section; but there is little doubt that the originally circular belt (as it appears in section) unbends, and becomes a slightly curved cylinder, the shallow concavity of which corresponds to the original central space where the ovum lay. At F is shown the belt of epithelium doubled up, and with a stalk of connective tissue issuing from its concavity. These various surviving conditions of the follicular epithelium appear to belong to follicles which had not become greatly expanded; the ovum had filled the central space exactly, and there had been no development of *liquor folliculi*. There are, however, aborted follicles of a much wider circuit, such as that represented at G; in this case the extensive belt of epithelium is thrown into folds, and it is further noticeable that the elongation of the epithelial cells is hardly perceptible, and that there is no uniform basement line either on the outer or inner surface of the belt.

Fig. 2 is an exact drawing of a group of three aborted follicles under a higher power (300 diameters); they represent the condition in which the surviving belts of follicular epithelium are most commonly found throughout the ovarian stroma. The concavity on the under surface of the central follicle is the original central space where the ovum lay, and the follicle has become unbent or straightened out; as regards the lowest of the three follicles, it may be taken to be a surface section through the rounded or convex aspect, the opposite and hidden aspect being the concavity of the slightly folded disc. Fig. 3 A, drawn with the same magnifying power, will serve to illustrate the cylindrical form of the cells. The shallow concavity *a* corresponds

to the original central space of the follicle. Along that curve are observed the ends of the epithelial cells that had originally been seated upon the zona pellucida of the ovum; they are now placed in an almost straight line (better shown in fig. 3, B), which is not so rigid or so like a basement membrane as that which unites the ends of the cells on the convexity. The original inner row of follicular epithelium does, however, at length acquire a fixity or cohesion which places it on a level with the original outer stratum, and the unbent or straightened belt of follicular epithelium may be described as (in the sectional view) a narrow cylinder packed with elongated columnar cells at right angles to its long axis. Two distinct rows of these cells may generally be made out, which adhere respectively to the two sides of the cylindrical space. The nucleus of the elongated columnar cell is at the attached end, so that the limiting membrane of the cylinder has a row of nuclei adhering to it on each side, and the centre of the cylinder is occupied by the free and protoplasmic ends of the cells interlocking. Such a grouping of the cells is sufficiently obvious in the lowest follicle of fig. 2. Not unfrequently, however, nuclei are seen more in the centre of the cylinder, as in fig. 3, B. In other words, the nucleus of the elongated epithelial cell is sometimes near the middle of the cell, although it is more commonly at the attached end. Each cell may be considered to be long enough to cross almost the entire area; the nucleus is most commonly at one end, which may therefore be called the attached end; the free or protoplasmic end interlocks with the nuclear and fixed end of the cell opposite, while sometimes the nucleus is more towards the middle of the cell, and thus appears in the middle of the cylindrical area.

These remains of Graafian follicles, being the more or less straightened or flattened belts of follicular epithelium, occur throughout the whole parenchymatous zone of the bitch's ovary in old age, and, it may be, to some extent before old age. They are wanting in ovaries that are obviously those of young animals, but I have found distinct traces of them in almost every other bitch's ovary that I have examined. In the case where I first observed them, they occurred in large numbers in a great many sections; in that particular ovary they were probably more

numerous than the unaborted follicles, ripe and unripe together. I am unable to say whether the exceptional number and distinctness of the aborted follicles was in that case owing to the greater age of the animal or to other causes. The same appearances may also be observed in the ovary of the cat; but the elongation of the follicular epithelial cells is not so marked as in the bitch. The observation which I have quoted from His, for the ovary of the cow, applies also to those of the dog and cat; if the traces of aborted follicles are not at first sight apparent, they may be readily found by examining the tissue round the circumference of a corpus luteum, in which situation the structures in question look as if they had been pressed upon and driven together by the enlargement of the corpus luteum. (Fig. 14, Plate VII.)

From the description given above of the elongation of the follicular epithelium and the acquisition of a uniform basement line along each side of the straightened or flattened cylinder, it will be obvious that there is nothing retrogressive in the individual elements of these structures; but that, on the other hand, as they occur scattered throughout the ovarian stroma, occupying certain exactly fitting spaces in the same, their appearance is suggestive of nothing but permanence or stability. The stroma of the ovary of the bitch is of such a kind that they are distinctly isolated throughout it I have not found them in the human ovary, nor in that of the mare, after a close search in a variety of cases. Even if they occurred at all commonly in the latter animal, the stroma of the ovary is so much composed of spindle cells and so little of fibres that the belts of follicular epithelium would hardly be isolated amidst the stroma in the same manner as in the bitch, and would not unlikely be merged in the stroma.[1] I have not examined the ovary of the cow for these obsolete strictures, but I have little doubt that the indistinct appearances seen by His and Waldeyer were of the nature that I have described.

[1] Extensively folded glancing membranes, corresponding to those described and figured by Henle as collapsed Graafian follicles, are found in the ovary of the mare. Born (*loc. cit.* p. 141) remarks that their great extent is against the notion that they are follicles; if they were unfolded, they would exceed the circumference of the whole ovary several times. There is much greater reason to think that they represent retrogressive corpora lutea.

2. *The Peculiar Cortical Structures in the Suprarenals of the Horse and Dog.* (*Figs.* 4–7, *Plates* VI. *and* VII.)

These well-known structures, first mentioned by Kölliker, are of uniform occurrence only in the suprarenals of the horse and dog; according to Henle, however, they are not wanting in the suprarenals of man and other animals, but they always occur isolated and over limited areas.[1] In many species of mammals, the structure of the suprarenals has probably not been examined, and the opinion has been expressed by v. Brunn that the single species of carnivorous animal and the single species of ungulate will be found not to stand alone among mammals in this respect.[2] However that may be, the occurrence of these peculiar suprarenal structures in even a single species is no less suggestive than if it occurred in every species. The rarity of their occurrence does not tend to set aside the suggestions that they give rise to, although it may widen the area of explanation.

The structure of these bodies, and their position relative to the rest of the organ, may be readily made out in any good section of a well-prepared suprarenal of the horse. Fig. 7, Plate VII. is a low-power view of such a section, made perpendicular to the surface. The outermost stratum is a zone of connective tissue of considerable thickness. Next to that comes the zone of peculiar structures above referred to. The most obvious reflection on looking at the figure, or at any perpendicular section through the organ, is that the zone of structures immediately beneath the surface belt of connective tissue is a stratum apart, and without the smallest resemblance to or transition towards the tissue that lies internal to it. The attempt of v. Brunn to show that these structures are really continuous at their lower ends with the tissue internal to them, and that there is essentially nothing to separate the one kind of structure from the other, can only be regarded as an effort of perverse ingenuity setting aside the common sense view of the case. The motive of this histological subtlety is to show that, even in the horse and dog, the cortical zone, as well as the centre, is of "connective tissue" origin, and not of "epithelial;" but that is a question of purely conventional interest, and the obvious fact

[1] *Handbuch der Anatomie*, vol. ii. p. 593.
[2] *Archiv f. Mikros. Anat.* vol. viii. p. 626.

remains, that the cortical structures, whether they be connective tissue or epithelial in origin, are marked off in the plainest manner from the substance of the organ immediately adjoining them.

In the suprarenals of the horse, these cortical structures occur with great regularity, in the perpendicular section, as elongated cylinders bent upon themselves, with their bending point at the surface, and their two tapering extremities pointing inwards. In the section through the cortex parallel to the surface, another aspect of them is revealed. The appearances are those of fig. 5, Plate VI. The cylinders in the surface view present a much greater variety of forms. They not unfrequently make a complete ring, with a small amount of connective tissue in the centre. Occasionally the cylinder is straight, with its rounded ends descending as if towards the depth. Many of them, also, are coiled or folded in a more complex manner. Putting the views in perpendicular section side by side with those seen in the surface section, the cortical zone may be said to be composed of a compact row of independent structures, presumably flattened discs with thin margins, and folded in such a way that their thin edges come together and point in a radial direction towards the centre of the organ. In the suprarenals of the dog (fig. 6, Plate VI.) the arrangement is less orderly; but the structures are no less unique as a class, and distinct among themselves.

The fibrous tissue that covers the surface of the suprarenal sends thin prolongations among the cortical bodies, and it is in these thin septa of connective tissue that the numerous small arteries enter the organ all round its convexity. The fibrous septa cover both the outer and inner surfaces of the bent or folded cortical cylinders. Within those compartments the elements of the cortical structures are arranged in the following way :—Each cylinder in section (disregarding the varieties of doubling or folding) is a belt-like aggregate of elongated cylindrical cells, arranged in close order, at right angles to the long axis. Fig. 4, Plate VI., drawn from a portion of a cylinder where the cells have been loosened, shows the forms of the cells and the general plan of their arrangement. Each cell has its nucleus towards one end, which appears to be its attached end. The cells are seated thus alternately on the opposite walls; their free ends overlap or interlock across the middle of the area, and each cell

may be supposed to extend almost the whole distance across. In the dog, the nuclei of the cells are somewhat nearer the middle, and the centre of the cylinder thus appears to be occupied by a row of nuclei (fig. 6). They are everywhere at right angles to the thin bands of connective tissue that bound the cylinders. Their bases on the two sides are in a close and uniform line, but there is no distinct basement membrane The cylinder is an aggregate of narrow and elongated cells placed side by side, and this aggregate, without further capsule or investment, lies in a space bounded by connective tissue.[1]

3. *Comparison between the Aborted Graafian Follicles and the Cortical Cylinders of the Suprarenal.*

This comparison is most readily made by reference to the figures. The group of three ovarian follicles in fig. 2 may be compared to the three cortical suprarenal bodies of the bitch in fig. 6. The uppermost body in fig. 6 has a certain resemblance to the folded or doubled belt of follicular epithelium F, fig. 1. Again, the two cortical suprarenal structures, fig. 5, from the surface section of the organ in the horse, are not unlike the aborted ovarian follicles B, C, and D, fig. 1. The drawings A and B of fig. 3, from the ovary of the bitch, show precisely the same forms of elongated cells as fig. 4, magnified the same, from the suprarenal of the horse; the long and narrow columnar cells are exactly alike in both cases, whether as regards the form, size, shape of nucleus, or the clear granular character of the cell-substance. The cells in both classes of structures are aggregated in close and regular order, the coherent ends on each side forming the boundary or limit of the aggregate, which lies, without being otherwise defined, within a space of the connective tissue. The morphological resemblance between the ovarian and the suprarenal structures is not only close, but it is complete. The only point of difference that suggests itself is that the nuclei in

[1] The contention of v. Brunn that the elongated columnar cells are of the nature of connective-tissue cells, and are structurally continuous with the fibrous septa that enclose them, rests on the occasional appearance of cells among them whose ends are pointed and prolonged into a thread-like process. Most of the cells have one end pointed, and some of them have both; but these are the ordinary modifications of form where columnar cells are packed together. For example, in the three or four layers of cells forming the epithelium of the trachea the same varieties of form occur, and the thread-like prolongations as well.

the ovarian structures are somewhat nearer the side, while those in the suprarenal structures are more towards the middle; but that not invariable difference, although it causes a certain amount of unlikeness between fig. 2 as a whole (ovarian) and fig. 6 as a whole (suprarenal), does not, when it is analysed, amount to anything.

So far, then, as a morphological likeness is concerned, the peculiar cortical structures of the suprarenal resemble the belts of follicular epithelium in the ovary that survive the decay of the ova. If there were any other structures in the whole range of animal histology to which the suprarenal cylinders might be compared, the resemblance now demonstrated might be a misleading one. The kind of structure is, however, unique; and, as it has an intelligible origin in the ovary, it is not improbable that at a remote period it had a corresponding origin in the suprarenal. But the more general considerations that are here suggested on the homologies of the suprarenal will arise most appropriately in the concluding section, and to some extent in the sections that immediately follow.

4. *The Limits of the Suprarenal Cortex and Medulla respectively, and the Structure of the latter as defined.* (*Figs.* 7–10. *Plate* VII.)

If the suprarenals of all mammals had been found to have so well-marked a marginal zone as that in the horse (fig. 7, *b*), there is little doubt that the term "cortex" would have been restricted to that zone, and all the substance lying within it would have been taken to be the medulla. The dog is the only other mammal that is as yet known to have that well-defined stratum of unique structures; but so little use has been made of this invaluable clue to the significance of parts within the suprarenal, that in one authoritative account of the varieties of the cortex among mammals, the dog has actually been classed with one group of animals and the horse with another.[1] It will be readily understood from this singular act of discrimination, that the subdivision of parts within the suprarenal has at present no very scientific basis. Cortex and medulla being correlative terms, all that remains over from the demarcation of the medulla becomes

[1] Eberth, art. "Nebennieren," in the *Handbuch der Lehre von den Geweben*, p. 510.

the cortex, and *vice versâ*. In the human suprarenal there is a limited central region which is much softer and more friable than the rest of the organ, and that has not unnaturally been named the medulla. In the suprarenals of other animals, the substance is of more uniform consistence throughout, but there is a marked difference in colour, especially after the action of chromium compounds, in the extreme centre of the organ, which has therefore been taken to be the medulla. The medulla being so defined, all the rest becomes cortex, and in most animals the cortex means (regardless of the etymology) the great bulk of the organ. This extensive cortex, again, has been subdivided from without inwards into three zones, the *zona glomerulosa*, *fasciculata*, and *reticularis*. The unique cortical structures in the dog constitute its *zona glomerulosa*, inasmuch as they are generally of rounded or oval form; the corresponding structures in the horse constitute its *zona fasciculata*, inasmuch as they are cylindrical and elongated, and the horse is therefore said to want the *zona glomerulosa*. Such, at least, is the conclusion that the highly objective method of the Germans leads to. The limitation of the extreme central region as the medulla is not without a real anatomical basis, but the anatomical fact upon which it is based is of a subordinate kind. The arteries, as is well known, enter the organ all round its periphery, and run for the most part with a radial course towards the centre, in which region the collecting vein or veins take origin. The medulla, as commonly defined, is the small area round the central vein (in the case of a small animal) or central venous lacunæ (in the case of a larger animal), and the extent of the peculiar colouring or of the softer texture corresponds exactly to the central venous region. But the parenchyma or cellular elements of the organ in that region are not different from the wide area of tissue external to it.[1] The true cortex of the organ is the external zone of unique structures that are found in the horse and dog, and whatever may correspond to that zone in the other species of mammals. The following observations are offered as evidence of what that correspondence in other species is.

[1] "The peculiarity of the medulla, discovered by Henle, of taking on a brown colour from the action of chromium compounds, does not justify its absolute separation" (Waldeyer, *Archiv f. Mikros. Anat.* xi. 190.)

This evidence is obtained in a very striking form from the examination of *accessory suprarenals* in the horse. Almost every suprarenal of the horse (and indeed of most animals) has adhering to various parts of its outer surface a number of tubercle-like bodies, which may be as large as a pea. Smaller masses are generally grouped round the larger accessory body, and in microscopic sections one finds a single comparatively large mass and a number of minute but complete portions of the same tissue round its margin. Fig. 8, Plate VII., is a low-power drawing of one of the smaller kind of accessory suprarenals from the horse. The central part is uniform throughout, there being no region of brown coloration, and there is only one way in which the body can be subdivided into cortex and medulla. The figure will, perhaps, hardly do justice to the very striking contrast between the two parts, for in the logwood preparation the marginal zone takes on a deep purple colouring, while the nuclei of the centre are less deeply stained and the protoplasm of the centre has a distinct light brown tint. On examining the cortex or margin of the body, we at once discover several well-marked examples of the remarkable cylinders that characterise the suprarenal proper; they consist of the same close-packed masses of long and narrow columnar cells, but, instead of standing at right angles to the surface of the body, the cylinders most commonly lie on their side. A few such cylinders, perfect in structure but somewhat out of position, are found in the cortex. The greater part of the zone, however, wants the characteristic structure. The perfect cylinders shade off gradually into bands of cells less perfect, and the margin of the body, over a considerable part of its circuit, is formed simply by a continuous narrow belt of round nuclei (see the lower side of fig. 8). In almost any accessory suprarenal of the horse, one may study the gradual *effacement of distinctive characters* in the structure of the marginal zone. It is this same process of effacement or degradation that has occurred in the cortex of the suprarenals of most mammals.

Fig. 9 is a companion figure to the last described. It is made from the thin end of the suprarenal of a fœtal guinea-pig somewhat beyond the middle of pregnancy; the sections from the thick part of the organ were quite the same, but the particular section has been selected for its convenient size. As in the case of

fig. 8, there is here only one way of subdividing the body into cortex and medulla. There is a narrow border (narrower than it appears in the figure, as the margin is cut somewhat obliquely) of deeply stained round nuclei, enclosing a uniform central substance. The central substance is a spongy mass of nucleated protoplasm, granular, and of a light brownish tint, and it comes out in strong contrast to the marginal zone. The marginal zone is precisely the same as that of the accessory suprarenal from the horse. If the section from the suprarenal of the fœtal guinea-pig be compared with a section of the organ from the full-grown animal, the narrow margin of deeply stained round nuclei will be found to be almost the same in the two cases, while in the adult the central substance has increased enormously. While the organ has grown, the central substance has acquired its venous region and the brown coloration peculiar to it, but the outer parts of it have become clearer and less tinted than in the fœtus, and have adapted themselves to the parallel radial arrangement of the vessels. The spongy substance of the fœtal centre has thus been modified differently in different regions, corresponding to the arrangements of the vessels in each region. The same modifications may be seen in small accessory suprarenals; a central region of spongy nucleated protoplasm (which is, however, usually excentric) passes gradually into a zone of radial columns, which, again, terminates abruptly at the narrow marginal beltof entirely different structure. That marginal belt is as distinct in the adult guinea-pig as in the fœtal; in the adult, it is the *zona glomerulosa* of authors, or the outermost of the three zones that form the cortex in the usual sense, and its glomeruli have often a curious resemblance to those cortical structures in the horse in which the characters are partially effaced. These glomeruli are not well marked at every point of the cortex in the adult guinea-pig; the effacement is sometimes more complete, and the marginal zone is only a narrow continuous belt of nuclear cells. The same explanation that has been given for the guinea-pig applies to the case of the human suprarenal (especially in its fœtal state) and to that of other common mammalia. There is nearly always a certain density of structure, with deeper staining and more nuclear character of cells, in the outermost stratum of the surprarenal. In the hedgehog this

outermost layer is almost wanting, and the organ, instead of being almost entirely cortex, as in the current mode of interpretation, is almost entirely medulla. But if the principle of an effacement of characters in the typical cortex be once admitted, none of the varieties of the outer zone need present any difficulty. The most general effect of this effacement of characters seems to be a sort of assimilation of the cortical structure to that lying immediately next it.

It may be said, then, by way of summary, that the most complete type of suprarenal is that of the horse; the loss of distinctive features which has occurred in the case of most mammals (and which may be traced in the accessory suprarenals of the horse itself) lies in the effacement or degradation of the cortex, while the great mass of the organ has persisted in all mammals alike, and presents essentially the same structure in all. This structure has now to be briefly considered.

In the fœtal condition, the central substance of the suprarenal shows the same character of protoplasm, and nearly the same texture throughout; this statement holds good for at least three species—man, cat, guinea-pig. All the tissue lying within the narrow marginal zone of deeply-stained nuclei (fig. 9, Plate VII.) is a kind of nucleated spongy protoplasm, granular, and (even in alcohol preparations) of a well-marked brownish tint. The extreme centre differs from the rest only in the character of the meshes that penetrate it; they are wider, more clearly defined, and more exactly round. In the extreme centre of the suprarenal from the human fœtus (2 to 3 inches long) these characters are well marked, and the tissue is not unlike one of the ordinary appearances of liver. There is a stage of development when the cells are not individually defined, and when the tissue is more accurately described as a nucleated protoplasm; at later stages the demarcation of the protoplasm round each nucleus becomes gradually apparent. It is to be further remarked, as a peculiarity of the tissue, that the brownish granular protoplasm is present in large quantity round the nucleus from a very early period. The meshes of the spongy tissue are the blood spaces, and they are lined by an endothelial membrane. The texture of the general medullary substance changes with the further development of these blood-channels. The extreme centre becomes, in

some animals, lacunar; while the more peripheral zone acquires the arrangement of radial columns (fig. 7, Plate VII.) The arrangement of radial columns depends upon the radial course of the blood-vessels in that zone. After piercing the cortex, the arteries assume the structure of capillaries, and it is by these radial capillaries, taking the place of branching arterioles, that the suprarenal is supplied throughout the greater part of its thickness. The capillaries end in the central vein, or system of venous lacunæ; and as the radial arrangement of vessels ceases, so also the columnar arrangement of cells comes to an end. The remarkable brownish colouring that is produced in the extreme centre by the action of chromium compounds corresponds generally to the region of collecting and outcarrying vessels. The colouring, when the reaction is complete, affects the nuclei as well as the protoplasm of the cells,[1] *and it also affects the blood-plasma inside the lacunar spaces.* But not only is the plasma of the blood within the central veins coloured brown by the action of the chromium compounds; the red blood-corpuscles are coloured a brilliant *green.* In the suprarenal of a horse, which was taken from the animal a few minutes after death and placed at once in a 2 per cent. solution of potassium bichromate, the central venous region was seen with the naked eye to be coloured a deep brown, as above described; and under the microscope there were observed in it, here and there, small areas of a bright green colour. These patches of green colour always corresponded to groups of blood discs. In the case of an artery seen in the longitudinal section, the lumen of the vessel was filled with a green mass, well set off by the purple colour of the muscular and other nuclei of the vessel wall; on closer examination, the green contents of this vessel were found to be entirely blood-corpuscles. More frequently the small green areas occurred in a space within the brown-coloured plasma inside the veins; there also the round contour of the individual corpuscles could be made out, while the brown plasma round about them was perfectly homogeneous. In another animal (hedgehog), which, however, was not obtained fresh, the blood-corpuscles were coloured brown, like the plasma and the parenchyma of the central region generally.

[1] This is, however, explicitly denied by v. Brunn (*loc. cit.* p. 624).

The brown colour of the central region may therefore be attributed to some property inherent in the outgoing blood. In like manner, the modifications of structure in the centre of the organ are dependent on the arrangement of the vessels in that region. In some cases the cells in the centre are the same (colouring apart) as the other medullary cells. In other cases, and notably in the horse, they differ somewhat, in a manner that will be afterwards mentioned. The other point that calls for notice, in connexion with the pigmented region, is its alleged nervous and ganglionic nature. The discussion of this matter has been greatly simplified by the publication, in 1866, by Holm, of a description, with drawings, of ordinary ganglion cells in no great numbers.[1] The matter now stands very much as it has been put by Kölliker in the 1867 edition of his *Gewebelehre:*[2] inasmuch as the true ganglion-cells have now been found, it is no longer to be supposed that the ordinary cells of that region have any connexion with the nervous system.

The central or general substance of the suprarenal, that substance which consisted of a spongy protoplasm in the fœtus, is, in the mature organ, a perivascular tissue. The cells are large nucleated elements, of granular substance and cubical or polyhedric shape; their substance is not unfrequently vacuolated. They are applied closely to the walls of the vessels, and their fasciculated or reticulated arrangements at different depths depend on the mode of distribution of the vessels among which they lie. The arrangement of the vessels is clearly shown in the plates illustrating the paper by Arnold.[3] The branches coming off from arteries in the cortical region have the simple endothelial structure of capillaries, and run at regular intervals and in parallel and radial lines towards the centre, where the arrangement becomes somewhat more reticular or irregular. In Arnold's figure, they are injected red in the outer half of the organ, and blue in the inner; but it is evident that they are in both regions of the same capillary structure and of unvarying calibre. Branches at right angles, or loops, here and there join the parallel vessels. In some animals the parallel intervals are

[1] *Sitzungsb. der Wien. Akad.* Math.-Naturw. Cl. 1ste Abth. 1866.
[2] *Op. cit.* 5th ed. p. 521.
[3] Virchow's *Archiv*, 1866.

small, and the columns of cells filling them are correspondingly narrow; in others again, as in man, the cellular collections are broader. The parallel course of these vessels is indicated at *c*, fig. 7, from the horse. Fig. 10 is taken from the deeper part of the tissue in the dog, and shows the more reticular grouping of the cells. The same figure shows somewhat indistinctly the meshwork of fine fibres by which the cells are supported in the intervals between the walls of the vessels. All the points relating to the perivascular nature of the suprarenal parenchyma have been clearly stated by v. Brunn, whose conclusion is: "With the exception of the central vein and the larger veins opening into it, and naturally, also, of the arteries running straight from the capsule to the centre and there branching, *all the vessels of the suprarenal have walls consisting only of the intima, upon which a loose adventitial connective tissue lies, containing the parenchyma cells in its meshes*" (*loc. cit.* p. 628).

There is one other point relating to the parenchyma that cannot be passed over. In the suprarenal of the horse, the cells in the extreme central or pigmentary region have a peculiar appearance, which has been figured by Kölliker. They are greatly elongated and narrow, with their nuclei at one end; and were it not that the free or non-nuclear ends were bounded by the endothelial membrane of the blood-channel, they might be likened to the epithelium of a mucous gland in the digestive tract. Both Kölliker and Henle have remarked a likeness between these cells and the long and narrow cells of the cortical structures. That resemblance, however, does not bear close analysis; the cells are merely an elongated variety of the ordinary perivascular cells, and the elongation occurs in those elements of the parenchyma that surround the larger venous spaces in the centre of the organ. A more cubical variety of them occurs in other animals, such as the cat and hedgehog; they invest the central veins in the same way as in the horse, and in the cross section of a vessel they look like a circlet of cubical epithelium applied to the outer side of the vessel wall. It is in these peculiarly grouped elements of the parenchyma that the brownish reaction with chromium compounds takes place.

Having described, in the first section, a certain form of cortical ovarian structure to which the cortex of the suprarenal (in its most perfect surviving form) is to be compared, we now come to consider whether there may be found any homology, such as will bear close analysis, for the general intra-cortical or medullary substance of the suprarenal. This second homologue is also found in the ovary, and that, too, under a variety of circumstances. It occurs (1) as an extensive deposit in the fœtal condition, and in early life throughout the whole medullary or vascular region as the *Keimlager* of Born; (2) it occurs as the corpora lutea of periodical ovulation, during the period of sexual maturity; and (3) it is apt to occur independently of ovulation, most commonly, perhaps, in old age, and in a form not distinguishable structurally from corpora lutea. The structure of this ovarian tissue, whether in the young or in the mature or senile ovary, affords always a perfectly accurate homology for the central parenchyma of the suprarenal. But the wide range of circumstances under which the ovarian tissue appears to occur, makes it difficult to indicate precisely the significance of the corresponding tissue in the suprarenal; and this part of the subject cannot well be treated otherwise than by describing the three forms of ovarian tissue in their order.

5. *Deposit of Plasma-Cells in the Substance of the Ovary in Early Life* (Keimlager, *Born*). (*Fig.* 11, *Plate* VII.)

The existence of this extensive and well-marked formation has not escaped the notice of certain writers; but in the works on general anatomy, and in the special treatises on the ovary, it has either been overlooked altogether or dismissed in the briefest terms, and without any serious attempt to elucidate it. Thus, in the elaborate work of Waldeyer, the description given by His several years before has been, indeed, referred to and so far confirmed, both in the text and illustrations, but without adequate discussion of the subject. Under the name of *Kornzellen*, His has given an accurate account of this ovarian tissue, but with some uncertainty as to the circumstances of its occurrence.[1] The most precise and intelligible statements on the

[1] "Beobachtungen über den Bau des Säugethier-Eierstockes," *Archiv f. Mikros. Anat.* vol. i. 1865.

subject are those of Veterinary-Surgeon Born of Berlin, in his memoir on the ovary of the mare.[1] As the work of those two authors appears to be insufficiently known in this country, I shall introduce here a summary of their observations.

According to His (*op. cit.* p. 165), there are found in the ovary of the cat, round the rudimentary follicles of the cortical zone, and at the second or third row of the same, nests of large oval cells (*Kornzellen*), with coarsely granular and opaque contents. In the subcortical zone, these structures attain a greater development, forming cords or tracts with an irregular network of cross branches. In the innermost stratum of the parenchyma, they occupy the greater part of the space left free by the follicles; and in the region of riper follicles they appear to constitute the membrana folliculi, or that bounding membrane of the follicle which the stroma supplies. The author here refers to drawings by Schrön, where similar cells occur; in Schrön's description of his plates they are said to be "perhaps the remains of former corpora lutea." Pflüger also is quoted as describing similar appearances; in the ovaries of small and sexually mature animals he observed yellowish patches suggesting corpora lutea. They consisted of innumerable fine molecules distributed around the nuclei of the stroma, at first in the depth of the organ and afterwards reaching to the surface strata. Pflüger thought that these appearances indicated a regressive metamorphosis of cells; His, however, observes that the cells to which these granules belong are in a state of active nutrition. The author further points out the differences between them and the ordinary spindle-cells of the stroma. They are round or oval, of considerable size (given in millimetres), with the nucleus often concealed by the granular substance. They are arranged in rows sometimes a single cell broad, sometime several cells side by side; the limits of individual cells in the longitudinal direction were not always clear.

As to the formation of these cells, His makes the following remarks, which have a direct bearing upon subsequent parts of the present paper. There seemed little doubt that they sprang from the spindle-cells of the stroma. An important relationship is that they make their appearance along with the capillary blood-vessels. At the places where the first granular cells appear, there are also found the outermost capillary loops; with the development of the granular cells, the capillary vascularity of the tissue increases, and all the larger heaps of granular cells are penetrated by a rich capillary network. The development both of capillaries and of granular cells is greatest in the membrana folliculi. Anatomically the granular cells stand to the blood-vessels in the relation of an adventitia; they encircle the blood stream not directly, but with the intervention of a wall formed of other elements. If the cells had directly formed the capillary vascular wall,

[1] "Ueber die Entwickelung des Eierstockes des Pferdes," *Archiv für Anat. und Physiol.* 1874.

they might have been regarded as the forerunners of the blood-vessels, or as vessel rudiments; as that is not the case, the blood-vessels must be considered to be the earlier structures. That the vascular formation of itself leads to the formation of cords of granular cells is negatived by the fact that, in the very vascular stroma of the hilus, the latter are not found.

As to the circumstances of their occurrence, prolonged observations failed to satisfy the author. It was conceivable that there were periods of activity and quiescence in their production. They were found in kittens eight to fourteen days old, and also in animals that were pregnant. It might be that the formation declined in the intersexual periods of the year, to gain in vigour at the other periods. In the investigation of the cow's ovary, the granular cells were much more obvious in the calf than in older animals.

This brings us to Born's accounts of the same kind of cells in the ovary of the foal. In the development of the organ there is a certain inversion of the germinal-epithelial surface peculiar to this species, which need only be premised. In the fœtal ovary, towards the end of pregnancy, the great bulk of the organ consists of a soft juicy tissue, the *Keimlager*, which is enclosed by the plate of germinal epithelium. At a later period the organ *diminishes* in size, at the expense of the *Keimlager*, while the follicular layer enclosing it goes on growing. The structure of this deposit of fœtal tissue is the following. It consists of a tissue for which the author considers that there is no analogue, unless it were the interstitial substance in the testicle of the foal. The ovarian tissue consists of large, juicy, polygonal, round, or oval cells, the diameter of which he estimates in millimetres at somewhat more than the figure given by His. They show, but only in the earliest stage of development, a close likeness to liver cells. They have a coarsely granular protoplasm, the granules of which are pigmented yellow. The nucleus is central and round, but often hidden by the granular substance. Their relation to the walls of the vessels is peculiar, and not quite the same as that described by His for the cat's ovary. With the increasing development of blood-vessels, the granular cells are separated into clusters, lying in meshes formed by the vessels. As the vessels rapidly form, and as the cortical or follicular zone grows, the granular cells disappear, traces of pigment granules remaining behind them, and in the ovary of the one-year-old foal they are found at rare intervals, and no longer in compact groups. In the ovary of the full grown animal nothing remained of this fœtal deposit. When the author comes to speak of the corpus luteum in the mare's ovary, he remarks: "It reminds one so strongly of the *Keimlager* that it might be considered to be a temporary restitution of that long vanished tissue" (*loc cit.* p. 148).

Fig. 11, Plate VII., is a drawing of this tissue from the ovary of the bitch early in life. The whole region inside the cortex was filled with these groups of granular cells; the clusters in the figure ran up as far as the subcortical zone of follicles, and

the same kind of tissue extended throughout the whole medulla and hilus of the organ. In an ovary of the kitten, again, I have found them only in small, isolated groups in the hilus stroma. They correspond closely with the descriptions given by His and Born, and they have obviously that relation to the capillary loops which both of those authors call attention to.

It would be perhaps rash to infer the existence of this fœtal tissue in the ovaries of all mammals; but for the mare, cow, bitch, and cat, it may be fairly said that the whole intra-cortical or medullary region of the ovary is occupied in early life by a vast collection of large granular nucleated cells, which are perivascular in their grouping.[1]

6. *The Structure of the Corpus Luteum.* (*Figs.* 12–14, *Plate* VII.)

I shall return in the next section to the observation of Born, that a corpus luteum might be viewed as a temporary restitution of the fœtal granular cells or *Keimlager*. The corpus luteum

[1] It may appear surprising that Foulis, working over the same ground (*Trans. Roy. Soc. Edin.* 1874–75), has not described this deposit of large granular cells in the medulla of the ovary. There is, however, a simple explanation of the omission. According to Foulis, the whole fœtal ovary is full of "primordial ova," grouped as "egg-clusters," among the thin bands of stroma. The stroma appears to be "actually saturated" with young ova. "The development of germ-epithelial corpuscles into primordial ova takes place in all parts of the ovary. . . . . All the embedded germ-epithelial clusters do not reach the stage of primordial ova, many of them abort and disappear, and perhaps furnish a pabulum for the more vigorous and healthy ones" (*loc. cit.* p. 364). "Although the eggs are so numerous in an ovary at birth, very few of them come to maturity. . . . . Many of the embedded eggs simply atrophy, and form a pabulum for the connective tissue corpuscles that surround them" (pp. 373–4). The cells that atrophy are obviously the *Kornzellen* of His and the *Keimlager* of Born, and, whatever their histogenesis may be, it is doubtful whether any good purpose is served by describing them as primordial ova and egg-clusters. Owing to this general designation of all the large granular cells as ova, the observations of Foulis appear to differ more widely from those of other authorities than is actually the case. At the same time, there is no doubt that isolated Graafian follicles may be observed forming in the ovary of the fœtal calf (about a foot long), as Foulis describes, in the very centre of the organ as well as in the cortex. In the new-born kitten, also, the cortical zone, which is so distinct in the adult organ, is hardly differentiated from the central part. But, according to the observations of Born in the case of the foal, the germinal epithelium, or *Keimplatte*, is marked off in the clearest manner from the *Keimlager*, and the two structures have, in his figure of the fœtal ovary, exactly the relations of a thin cortex and an extensive medulla. That is also the relation in the ovary of the bitch from which fig. 11 has been taken.

has to be considered here with reference to its intimate structure.

The long-cherished belief that the corpus luteum was a clot of blood filling up the newly-emptied follicle has now almost entirely disappeared from text-books, and the explanation of the structure which v. Baer gave in 1827 has been abundantly confirmed and made to pass current. The corpus luteum is a cellular hyperplasia of the wall of the follicle (ovarian stroma), which encroaches upon the follicular space in a continuous thick layer thrown into folds, filling up the space in most animals, and appearing as a solid, rounded body, with a folded appearance exactly like that of the cerebral convolutions.[1] A fibrous core is enclosed by the convolutions as they gradually meet in the centre. In larger animals, the fibrous core is traversed by veins or venous lacunæ, which had covered the inner surface of the cellular hyperplasia before its convolutions had closed in;[2] in smaller animals, like the cat, the fibrous core is of small extent, and there may be only one central vein.

If reference be now made to fig. 13, from one of the convolutions of a well-formed corpus luteum of the mare (which presents a simpler plan of structure than that described by His for the cow), the nature of the tissue and its vascular arrangements will be at once apparent. The upper surface, with the central space, is towards the interior, and the rounded end is towards the ovarian stroma. This folded belt of tissue is transversed in the most regular way by parallel vessels running straight from one surface to the other, or rather from the periphery to the centre. These vessels are all of the same size and of the same capillary structure. The proper cells of the structure, which are somewhat vaguely outlined in the figure, are deposited in regular columns between the parallel vessels; there are frequent cross branches between the parallel vessels, and the plan of structure is in some places more reticular than radial. That more reticular arrangement is shown in a part of fig. 13, and also in fig. 12, from the corpus luteum of the bitch. The latter figure shows traces of the spindle-celled mesh-work by which the large granular

[1] This comparison is made by Farre, art. "Ovary," in Todd's *Cyclopædia*.

[2] Schrön, *Zeitschrift f. Wissensch. Zool.* xii. 422.

elements are supported in the intervals between the vessels. It is chiefly from the numerous large arterial trunks running round the periphery of the corpus luteum that the radial capillaries come off; there are, however, some arterial vessels in the fibrous core, whose capillary branches may therefore be supposed to cross the tissue in the opposite direction. The proper cells of the corpus luteum are large, nucleated, spherical, or polyhedric elements, with a granular protoplasm. In the mare and bitch they are scarcely at all pigmented or tinted when the growth is at its highest point.

The corpus luteum, then, may be said to be a structure composed essentially of large protoplasmic cells with a distinct perivascular arrangement. It is not necessary to dwell on the curious resemblance between that kind of structure and the suprarenal parenchyma. I shall, however, introduce here the observation of Schrön on the vessels of the corpus luteum. "The remarkable point," he says, "in the vascular distribution within the corpus luteum is that the veins do not return in the same track by which the arteries entered the tissue, but that a large central vein collects the whole blood of the corpus luteum" (*loc. cit.* p. 422). In larger animals it is not one single vein, but rather a lacunar system of veins that collects the blood.[1] In like manner, in the suprarenal, the venous blood is collected in one central vein in the case of small animals, and in a system of venous lacunæ in the case of the larger mammalia.

The histogenesis of the cells of the corpus luteum concerns the present subject only indirectly; and, beyond the observations in the next section, I must content myself with referring to the evidence that His has collected, to show that the corpus luteum arises from the cells of the ovarian stroma, and chiefly from those of the *membrana folliculi*, in exactly the same way as the *Kornzellen*.

7. *Structures resembling Corpora Lutea in Senile Ovaries.*

The observations that are to follow have not been collected in order to support any particular part of the general theory;

[1] "In smaller animals a single collecting vein may occur instead of the venous plexus in the centre of the corpus luteum" (His, *loc. cit.* p. 185).

whatever they may point to, it seems necessary to call attention here to certain perivascular formations of plasma-cells that do not seem to depend on periodical ovulation. According to Waldeyer,[1] the wall of the follicle, when the ovum aborts after reaching maturity, takes on the same hyperplastic action as when a corpus luteum is formed, only the new formation is very much less extensive. The case in which I have found these corpora lutea not of ovulation most abundantly was that of an old bitch with very numerous aborted follicles. At many places in the stroma, patches of yellow granular cells occurred, corresponding in origin and in appearance to the *Kornzellen* of His. It was obvious, at the same time, that these patches grew to form structures exactly resembling corpora lutea. Thus, at a particular part of the periphery of the organ in section, there occurred four or five somewhat circumscribed areas, marked off by corresponding indentations of the surface; they looked as if each of them had for its framework a loop of blood-vessels shooting out beyond the surface, and the germinal epithelium covering them had grown into wart-like excrescences. Two of these areas had exactly the structure of corpora lutea, while the others merely contained a few rows of yellow granular cells in the ovarian stroma, although there was no doubt that they were advancing in the same direction as their neighbours. Numerous aborted follicles lay round about, but these patches of granular cells did not seem to belong to particular follicles, but rather to the circumscribed vascular territory. It was, at the same time, evident that the new formations did not begin in the connective tissue cells of the wall of the follicle, but in the stroma adjoining. There were a good many large and perfect corpora lutea in these ovaries, but the animal was not pregnant, nor had been so, as far as was known. The ovaries also contained a number of cysts, and there was a certain amount of evidence that the cysts had resulted from some of the corpora lutea becoming fluid. Again, in a series of ovaries that I obtained from eight mares killed at a horse-knacker's in London, there were evidences of the forma-

[1] Article "Eierstock," in the *Handb. der Lehre von den Geweben.* p. 573. In his monograph, *Eierstock und Ei*, p. 97, the statement is made only for the fowl's ovary, and a figure is given of the new cellular formation round the wall of the aborted follicle.

tion of large corpora lutea other than those of pregnancy. In two of the cases, from aged animals, the ovaries were partly cystic and partly occupied by corpora lutea. Two and even three of these cellular masses occurred in an ovary, as large as walnuts, and in one case the tissue was in so diffluent or broken-down a condition as to suggest the formation of a cyst. In the last number of this *Journal* I digressed from the subject under treatment to describe the occurrence of a remarkable perivascular formation of the same kind of tissue in the ovary of a woman aged 75.[1] These observations are fragmentary, and may seem to belong more to pathology; but in treating of senile conditions, pathological and normal are not to be sharply distinguished. I have only to quote further an observation made incidentally by Foulis in his memoir on the development of the Graafian follicles; in every old ovary of the cat and rabbit he found patches of yellow granular cells,[2] and as they are not specially described as the early stages of corpora lutea, it may be presumed that they occurred independently of ovulation.

There is thus considerable reason to think that the ovarian stroma may produce the characteristic formations of plasma-cells under a greater variety of circumstances than the present theory of corpora lutea takes cognizance of. In addition to the fragmentary evidence of senile formations which I have given, there might be collected a number of corroborative facts from a re-examination of the so-called false corpora lutea in various animals. Thus in the ovary of the mare, there are often several such structures in process of growth at the same time. They are elongated, flask-shaped formations, obviously taking origin from the hyperplasia of cells belonging to a loop of vessels; the histogenesis of the cells can be very clearly followed in them, and all stages may be observed from the earliest linear streak or narrow loop of reddish pigmented substance to the extensive flask-shaped or globular corpus luteum. According to Born, the false corpora lutea in the mare may be as large as beans, and if that be admitted, it is at the same time probable that the distinction between false and true corpora lutea, at least in that animal, is

[1] This *Journal*, vol. xii. p. 546.
[2] *Trans. Roy. Soc. Edin.* 1874–75, vol. xxvii. p. 371.

not so rigorous a distinction as it is commonly represented to be.[1] The formation of these structures under all circumstances may be attributed, for want of a more particular causation, to a hyperplastic tendency inherent in the ovarian stroma; and it may not be amiss to repeat the remark of Born, that the corpus luteum was as if a temporary or occasional return of the abundant protoplasmic tissue that characterised the ovary in its fœtal condition.

8. *Suggestions towards a General Conclusion.*

It will now be convenient to review briefly the evidence that has been collected. Some of it relates to the suprarenal by itself, and some of it to the ovary by itself, while the points of resemblance or homology between the organs are such as almost to suggest themselves.

Firstly, as to the suprarenal, the evidence goes to show that its essential subdivision is into a narrow marginal or cortical zone and an extensive region of tissue within it. The marginal zone shows a tendency to lose all characteristic structure, and to be reduced in extent, while the central substance has the appearances of durability and efficiency. Sufficient indications remain to show what was probably the original nature of the cortical part of the organ. The structures composing it in the horse and dog resemble nothing in the body but the remains of obsolete Graafian follicles or egg-capsules. If the resemblance had been to the perfect condition of ovarian follicles, it would have been a sufficiently striking resemblance; but as it is to the surviving traces of these structures in the ovary that the suprarenal cortex is to be compared, the comparison is one much more suited to the circumstances, inasmuch as the suprarenal cortex throughout the whole mammalian class shows the true indications of obsoleteness. Two things are to be kept in mind in connexion with the obsolescence of Graafian follicles: first, that it is only the superfluous follicles that become the subject of it; and, second, that in these cases the follicular epithelium, if one may so speak,

[1] The quantity of such tissue present in the ovaries must depend on the frequency with which the periods of heat recur. In the mare, for example, these periods recur at intervals of three weeks during several months of the year, and on each occasion a corpus luteum no doubt begins to form. The extent to which these structures may grow when there is no pregnancy does not appear to be known.

composes itself to a vigorous existence after the ovum that it enclosed has decayed.

The great mass of the suprarenal, however, does not show the same traces of obsoleteness as the cortex; otherwise it would hardly have continued to be an organ of the body. The perivascular plasmatic tissue of which it is composed may have a certain particular homology, and may have had a function at one time that is now obsolete, but it seems to have been adapted to new uses, and so to have held its ground. The remarkable reaction of chromium compounds with the centre of the tissue, and primarily, as I have given some reasons for believing, with the venous or outgoing blood of the organ, points to some very particular change wrought upon the blood passing through it.

The relatively great size of the suprarenal in fœtal life has no doubt some significance for the antecedents of the organ.[1]

Secondly, as to the ovary, there is the evidence relating to its cortical or follicular zone which I have already referred to, and there are the very singular facts concerning the rich masses of plasma-cells in its medulla. Perhaps the most remarkable of these facts is that described by Born for the foal's ovary. The

[1] This holds good for several mammalian species whose development has been described, and will probably be found to hold good for others. In the human fœtus, about the second month, the suprarenal is said actually to exceed the kidney in size. About the tenth to twelfth week it appears from the surface to be about the same size as the kidney, but it is really not so large; for its under surface is deeply excavated to receive the upper end of the kidney, and when this thin prolonged margin is allowed for, the mass of the organ is considerably less than that of the kidney. This becomes obvious on cutting a series of sections through both organs embedded together. An opinion has arisen that there is something unique in the size of the suprarenal in the human fœtus. Thus Duckworth (*St. Barth. Hosp. Reports*, vol. i. 1865) quotes the following opinion: "Professor Allen Thomson has informed me that, according to his observations, the suprarenal capsules do not present that preponderance in any other mammalian animal which they exhibit in man." Perhaps so; but it is only a trifling difference in degree. Turning to the published accounts, Bischoff states that in the fœtal guinea-pig at the fourth week the suprarenals are "almost as large as the kidneys," and in his drawing they appear much about the same size (*Entwickl. des Meerschweinchens*, p. 55, and fig. 67, plate vi.) In the same author's memoir on the development of the dog, he says that in the embryo four weeks old, "above the kindeys lie the scarcely smaller suprarenals" (*Entwickl. des Hunde-Eies*, p. 118, and fig. 45 H. plate xiii.) The memoir on the rabbit does not carry the development so far as the origin of the permanent kidneys, and I have not been able to consult his memoir on the roe-deer.

ovary at the tenth month of pregnancy was actually as large as that of the full-grown mare. It was 6 c. long, 56 mm. broad, and 34 mm. deep. At the time of birth the ovary had absolutely decreased in size. In the foal 47 hours old, it was 33 mm. long, 16 mm. broad, and 19 mm. deep. In the foal 33 days old, the measurements were: 36 mm. long, 15 mm. broad, and 17 mm. deep. At the age of one year the ovary measured 4 c. long, 24 mm. broad, and 26 mm. deep, or very considerably less than at the tenth month of fœtal life.[1] The enormous size of the fœtal ovary depends entirely upon the existence of the *Keimlager* or collection of granular perivascular cells. In Born's figure, it appears as a uniform brownish mass which occupies the whole organ except a narrow margin. It almost entirely disappears by the end of the first year; so that, although the rest of the ovary grows proportionally with other organs, it is at that time much smaller absolutely than in the fœtal condition.

Another remarkable incident in the ovarian history is the periodical formation of a corpus luteum. Morphologically considered, the corpus luteum is no doubt a survival, and it is very questionable whether the surviving structure has been adapted to any modern function or use. It was with a view to illustrate the morphological side of the problem that I investigated the primitive formation and subsequent adaptation of the uterine decidual tissue in the case of the guinea-pig.[2] There were two striking points of relation between the uterine formations and the ovarian. Not only does the primitive decidual tissue resemble exactly the tissue of its contemporaneous structure, the corpus luteum, but the later or placental formation is an intelligible and beautiful adaptation of or improvement upon the type of structure which is common both to the corpus luteum and the primitive uterine hyperplasia. The theoretical conclusion (forming, however, no integral part of my former paper) was that "the decidual capsules of the guinea-pig may be regarded as the modern and efficient representatives of nutrient or enclosing structures, of which the corpora lutea in the ovary are the obsolete but still persisting types" (*loc. cit.* p. 541), and it followed

[1] *Loc. cit.* These variations in size had been previously mentioned by Chauveau and others, but the minute anatomy does not appear to have been described.

[2] This *Journal*, vol. xii.

from the detailed description of which the paper consisted, that the decidual capsules in the guinea-pig were themselves merely temporary enclosing structures upon whose foundation the true nutrient organ or placenta was afterwards built up.

The ovarian tissue to which the suprarenal parenchyma is compared bears evidence of being, both in its fœtal and in its mature form, itself a survival from a former condition, and it may be said to be a survival incidental to the change of type to the viviparous mode of reproduction characterising the mammalia. The correspondence with the suprarenal in structure holds good both for the fœtal deposit and for the occasional productions of the tissue in mature life, but it is the fœtal deposit that accurately corresponds in extent and in the suggestive relation between cortex and medulla.

The evidence stated above has its own value, entirely independent of the questions relating to the development of the suprarenals, or to their structure in the other vertebrata, or to the occurrence of the organ in both sexes.[1]

That evidence all points in one direction, but it would be hazardous in the extreme to attempt to solve the details of the suggested homology. It would be a task of the greatest difficulty to place the observations here collected in their true relation to one another, while nothing would be easier than to piece them together wrongly. I prefer to leave them as the *disjecta membra* of a theory, which may assume its true shape when the observations are more complete, and when there have been formulated the general principles of obsolescene and heredity which are necessary for their interpretation.

[1] The only animal in which I have found a marked difference in size between the suprarenals of the male and of the female is the *Ornithorhynchus*; the organ in the female was about four times as large as that of the full-sized male. In another male, however, I found it about the same size as in the first female; the animal had been shot in October, the month of rut, and all the sexual glands were much enlarged. The structure of the suprarenals in the Monotremes is curious, but somewhat unintelligible.

EXPLANATION OF PLATES.

Plate VI.

Fig. 1. Various forms assumed by the zone of follicular epithelium after the abortion of the ovum. × 90. *a*, The collapsed vitelline membrane.

Fig. 2. A group of three obsolete Graafian follicles, as they are found lying in the ovarian stroma. × 300.

Fig. 3, A. A small obsolete Graafian follicle, consisting of the straightened or unbent zone of follicular epithelium. *a*, The shallow concavity which represents the original position of the ovum; elongated cylindrical form of epithelium, with nucleus at one end. × 300.

Fig. 3, B. A similar obsolete follicle. *a*, The position originally occupied by the ovum; the nuclei in some cases occupy the middle of the epithelial cells, but they are generally situated at one end. × 300.

Fig. 4. Portion of one of the peculiar cortical structures in the suprarenal of the horse, as seen in the vertical section; elongated cylindrical form of cells, with nuclei alternately at the opposite ends. × 300.

Fig. 5. Two slightly folded circular belts of elongated cylindrical cells, as seen in the surface section of the suprarenal of the horse. × 90.

Fig. 6. Three of the peculiar structures in the cortex of the dog's suprarenal, in vertical section. × 300.

Plate VII.

Fig. 7. Low-power view of a segment of the cortex from the suprarenal of the horse, vertical section. *a*, The fibrous tunic; *b*, the zone of peculiar cortical bodies; *c*, zone of polyhedric nucleated cells, usually reckoned as belonging to the cortex, but more properly constituting the outer part of the medulla; radial vessels of simple endothelial structure transversing it. × about 50.

Fig. 8. Small accessory suprarenal of the horse, showing the true relation of cortex and medulla. × about 50.

Fig. 9. Cross section of the suprarenal of a fœtal guinea-pig, about the middle of pregnancy, showing the same relation of cortex and medulla as in fig. 8. × about 50.

Fig. 10. Portion of the interior (zona reticularis) of the dog's suprarenal; large polyhedric nucleated cells set in a fine mesh-work of fibres. × about 250.

Fig. 11. Groups of granular nucleated cells from the subcortical zone of the ovary in a young bitch. × about 250.

Fig. 12. Portion of a corpus luteum of the bitch; large polyhedric nucleated cells set in a mesh-work of fibres derived from the walls of vessels. × 150.

Fig. 13. Convolution of a corpus luteum of the mare, showing the large granular cells arranged in radial columns between vessels of simple endothelial structure; on the upper side of the figure is shown a portion of the central venous space. × 90.

Fig. 14. Low-power view of segment of corpus luteum in the bitch, bounded above by a belt of ovarian stroma. *a*, Three aborted Graafian follicles; *b*, the corpus luteum. The surface epithelium of the ovary slightly detached on the left side. × about 50.

ON THE ANATOMY OF GENU VALGUM. By EDMUND OWEN, F.R.C.S., *Lecturer on Anatomy at St Mary's Hospital, London.*

AT an October (1877) meeting of the Surgical Society of Paris, M. Verneuil remarked that the cause of genu valgum had been ascribed by various authorities to a pathological condition of the ligaments, of the muscles, or of the bones of the knee-joint; and that as regarded the influence exerted by the bones, some writers, as MM. Ollier and Tripier, considered it to be the result of increased activity in the growth of the internal condyle of the femur, whilst others attributed it to atrophy of the external condyle.

Foremost among the latter class of observers is Professor Humphry, who, in his *Treatise on the Human Skeleton*, published in 1858, wrote (p. 535): "Suppose, however, that the whole surface of the outer condyle has not descended to the same level with that of the inner condyle, or, which is no uncommon thing, has been flattened by the weight of the body; then, although the leg may occupy its natural position when the knee is bent, it will, during extension, slant more outwardly, instead of becoming vertical, and will attain its greatest obliquity when the joint is straight. This is what occurs in cases of 'knock-knee.'" M. Verneuil, on the occasion above referred to, advanced a third theory, which was to the effect that though the deformity was sometimes due to hypertrophy of the internal condyle of the femur, at other times it was the result of an enlargement of the inner tuberosity of the tibia.

The object of this short communication is to show that the atrophy of the articular masses of bone on the outer side of the deformed knee, together with the hypertrophy of the inner tuberosity of the tibia and of the internal condyle of the femur, are the direct result of a slackness of the internal lateral ligament.

To those who account for the deformity by the theory of enlargement of the internal condyle of the femur, one is inclined to put the question, "Why should the internal condyle be more

prone than the external condyle to take on inordinate growth?" The experiments of MM. Ollier and Tripier show that artificial irritation of either femoral condyle will give rise to increased growth of that condyle; in the same way, probably, that the ivory pegs employed in the treatment of ununited fracture cause an excessive development of new bone. But these experiments do not offer a physiological explanation of the *cause* of the enlargement of the internal condyle in knock-kneed subjects. The means of feeding the external condyle are similar to those of feeding the internal condyle; so also with the tuberosities of the tibia. Yet one rarely observes hypertrophy of the outer masses of bone in the knee-joint and atrophy of the inner—conditions which would cause the salient angle of the knee to be directed outwards. The deformity of "bandy-leg" is, in my experience, only exceptionally the result of a want of proper proportion between the articular masses of bone; the outward bowing of the knee being secondary to the curvatures assumed by the femur and tibia. In the out-patient department, at the Hospital for Sick Children, where one meets with an unfortunately large number of bandy-legged patients, I have found but one instance of the deformity resulting from changes in the articulation itself; this was in a girl approaching puberty.

If the deflection of the tibia in genu valgum were due to excessive growth of either the internal condyle of the femur or of the internal tuberosity of the tibia, or of both these masses of bone, the pressure existing between them would be so increased that the internal lateral ligament would be rendered excessively tight. But in many rickety knock-kneed subjects a considerable amount of lateral rocking motion can be obtained in the affected joint, even when the leg is firmly extended upon the thigh. Such movement cannot be imparted to the healthy joint in the position of extension, much less could it exist in a knee whose internal lateral ligament had been rendered tense from increased intra-articular growth of bone. Given a subject whose lower extremities are too weak for the support of the weight which they are called upon to bear, either the bones will bend and possibly give rise to bandy-legs, or the ligaments will yield, and knock-knee, and probably also flat-foot, will be produced. It will be the internal lateral ligament of the knee which will give

way, not the external lateral ligaments, because the latter derive support and security from the tendon-like fascia lata on the outer side of the limb, as well as from the tendon of the biceps itself. The fascia lata descending from the hip-bone to the outer tuberosity of the tibia and to the head of the fibula, and containing all the fibres of insertion of the tensor fasciæ femoris, and two-thirds of those of the glutæus maximus, finds no equivalent on the inner side of the knee. The support afforded by the sartorius and gracilis to the inner side of the knee is relatively and absolutely small. In a well-marked case of knock-knee the important band of fascia, to which attention has just been directed, may be made out, especially when the leg is extended, running like a tight bow-string across the retiring lateral angle of the joint, considerably in front of the tendon of the biceps.

In most knock-kneed children the ligaments throughout the body are markedly weak and lax; but the allied fascia lata and biceps having provided against an outward bowing of an enfeebled knee, an inward falling of the joint may be anticipated. The more the internal lateral ligament yields, the less becomes the pressure between the internal femoral condyle and the inner tuberosity of the tibia. So these masses of young and growing bone, now free of a pressure which should regulate and control their development, grow without restraint into the interior of the articulation. And during this time the outer side of the joint is subjected to a necessarily increased amount of pressure, which moulds and retards the growth of the plastic masses of bone as thoroughly and as surely as does the tight bandaging arrest the growth of the Chinese girl's foot-bones.

The rational treatment, which I apprehend consists in diminishing the pressure borne by the outer side of the deformed joint whilst it increases that on the inner side, the joint being quiescent the while, reproduces a normal condition, provided only that the bones are plastic enough to be still amenable to the moulding influence of the pressure.

THE GROWTH OF BONE FROM THE ARTICULAR CARTILAGES. By Professor HUMPHRY, F.R.S.

IN his papers in the tenth volume, and in the last number, of this *Journal*, Dr Ogston has called attention to the bone producing function of articular cartilage. I am sorry to be obliged to differ from Dr Ogston in some of the views which he has advanced, and cannot but think that he has considerably overestimated that function both in the growing and in the adult periods, and also in diseased conditions.

That it cannot contribute much to the length of the bones during the growing period is proved by the fact that there is but little growth, and consequently but little addition to length, in the epiphyses either on their articular or their apophysial surfaces, and the growth which does take place is less in the articular part of the cartilage than in the part at a distance from the joint, that is, near the shaft. The elongation of bones is effected almost entirely by addition to the shafts through the medium of the epiphysial lines of cartilage, the cell growth and ossification taking place chiefly on the apophysial sides of these lines; and the growth being thus almost confined to these lines, and to one side of them, they remain always at nearly the same distance from the articular surfaces. The articular parts of the epiphyses are, from their proximity to the joints, obviously ill-suited for much cell proliferation; and the processes of ossification are provided for at a greater distance from the joints, through the medium of the epiphysial lines, in order that those processes may go on undisturbedly and with the requisite speed. I need scarcely say that had the length of the bones been effected by the growth of the epiphyses equally, or nearly equally, with that of the shafts, the epiphysial lines would soon have come to occupy a position much nearer to the middle narrow parts of the shafts, a position which would have been incompatible with the requisite strength of the bones; whereas by the provision I have mentioned, they are retained in the broader parts near the articular ends, and the requisite cell growth and ossification can go on in a quiet region without imperilling the

strength of the skeleton. Microscopical sections show, as Dr Ogston represents, the columnar arrangement of the cells, and the ossifying processes in the cartilages of the epiphyses; but the signs of activity are far greatest on the shaft side of the epiphysial lines, and are least in the region of the articular cartilages. I am not sure whether Dr Ogston includes the epiphysial cartilages in the term "articular cartilages." The ends of the bones are formed in great measure from the former, as may be seen in sections of growing bones, and to a small extent only from those parts of them near the joint surfaces which are usually denominated articular cartilages.

In the grown bone the osseous structure next to the articular cartilage does not undergo any greater wear than at other parts of the bone, and does not, therefore, stand in any greater need of the assistance of cartilage to maintain its proper condition. A microscopical section of the articular end of such a bone shows the stratum of cartilage immediately bounding the joint to contain very few cells; then comes a thin layer in which the cells are more or less flattened and disposed in a direction parallel to the surface. This is followed by a stratum making up the greater part of thickness of the cartilage, in which the elongated capsules, containing three, four, or five cells in single file, are placed vertically with regard to the surface. They are not very numerous, and rather lose their regularity where nearest to the bone. Then, intervening between these and the irregular line of true corpuscular bone, is a thin stratum in which the cartilage cells are dark and opaque, evidently undergoing or having undergone calcification, and forming the layer of calcified cartilage which has been described to exist there. The surfaces of the bone and of the calcified cartilage are quite distinct and defined, though irregular processes of the one run into and are adapted to corresponding depressions in the other. This layer of calcified cartilage, which Dr Ogston hardly takes into account, must, it need scarcely be added, form a barrier to any regular process of ossification taking place in the articular cartilages, and to any addition to, or repair of, the bones from them. The articular cartilages can scarcely, therefore, be regarded as being "formed of cells in active, constant, and definite growth." Their function in this respect, I apprehend, under ordinary circumstances must

be limited to the repair of the slight amount of wear which takes place in themselves during the movements of the joint. I say slight amount, because the friction is, in the healthy state, reduced almost to nil by the polished character of the surfaces and the presence of the synovial fluid. It has also to be borne in mind that the articular cartilages are quite extravascular, and are in the contiguity of but a scanty blood supply, and that upon one side only, so that their nutritional condition is incompatible with an active function of any kind.

Thirdly, with regard to morbid conditions. Bone growths upon the circumference of the articular ends are very frequent attendants upon changes in the articular surfaces, more particularly upon ulceration and chronic rheumatic arthritis; and these formations must be periosteal, for after adolescence there is no other tissue from which they can be produced. On the articular surfaces, on the contrary, bone deposit is comparatively rare and scanty, being for the most part, where it does occur, only in sufficient quantities to fill up the cancellous apertures resulting from ulceration, and to unite or ankylose opposed surfaces which may be in contact, or to harden the bone into a porcelain-like condition when the surfaces are rubbed upon one another, as in rheumatism. But in these instances the cartilage has been removed, and cannot contribute to the new formation which must take place in the bone cancelli themselves irrespective of cartilage. If it takes place before the removal of the cartilage and through its medium, as stated by Dr Ogston to occur in some cases of scrofulous and rheumatic arthritis, it is to a very limited extent. I have seen specimens of the kind referred to by him where small nodular bony formations have taken place upon the articular surfaces, but they appeared to be the result of ossification of newly formed osteoblasts rather than of the articular cartilage itself. The articular ends are often flattened and widened and otherwise deformed, but rarely deepened, or lengthened, by disease. I do not remember a specimen in which there was clear evidence of the latter having occurred to any marked extent.

The direction of the cancellous plates upon which Dr Ogston lays so much stress will be found, I think, not to have any special relation to the articular cartilages, or to be a sure indi-

cation of chondrogenous formation, but rather to have relation to the line of weight and the direction of the forces to be resisted, and therefore to be, as a general rule, parallel to the long axis of the body, especially in the long bones of the lower limbs and in the vertebræ; and this is the case throughout the shafts, or periosteal parts of the bones, as well as in the extremities. In the case of the adult femur, for instance, there is a marked arrangement of plates descending in parallel lines from beneath the upper surface of the head of the femur to the lower part of the neck, where they impinge upon and are lost in the wall of the shaft about the lesser trochanter. The plates retain their vertical direction through the shaft, though in the narrow part they are compressed into the hard wall, and are therefore less conspicuous. As the bone expands into its lower end the plates separate from one another and from the wall, and again become more obvious, still continuing their vertical direction. In the situation of the now ankylosed epiphysial line they are blended to a greater or less extent, irregularly; but from it they again descend vertically to the articular surface, in greatest numbers and in greatest strength towards the under part of the outer condyle, which, in the erect posture, is situated under the head of the bone, and most directly, therefore, in the line of weight. I need scarcely say that in the greatest part of their extent these vertical plates are derived from the periosteal osteoblasts, and not from cartilage. In the vertebræ also, where the bone is to a considerable extent periosteal, the plates of the cancelli have in the main a vertical direction. In the tarsal bones the chief direction of the plates is radial from the summit of the astragalus, which is the key bone of the plantar arch, to the bearing points upon the ground, that is, backwards and downwards to the heel, and forwards and downwards to the balls of the toes. The same law will be found to apply generally throughout the skeleton, and will explain the direction of the plates in the cancellous as well as in the harder parts of the bones, in those which are periosteal as well as in those which are chondrogenous.[1]

To what immediate nutritional agency the adjustment of the

[1] Attention was, I believe, first directed to the arrangement of the cancelli with reference to the weight which the bones have to bear in my *Treatise on the Human Skeleton.*

bone plates to their requirements is brought about—how, in short, they come to be arranged vertically to the surfaces of contact, and parallel to the lines of weight or force—I cannot tell. It evidently is not dependent either upon the chondrogenous or the periosteal origin of the bone, forasmuch as it is alike in both instances. It cannot be a result of pressure determining a deviation inwards of the layers of the bone, as suggested by Dr Ogston in the case of the os calcis, for pressure would give a determination to the layers in an opposite direction, and cause a flattening or horizontal, instead of a vertical, disposition of them. There is apparently nothing inherent in the processes of ossification to determine it; for in cartilage, where those processes can be best seen, the incipient ossifying streaks shoot out radially from a centre, and in a similar manner in all directions, and not till a subsequent period do the cells assume a columnar arrangement corresponding with the long axis of the bone or with the lines of force directed, or to be directed, upon the bone. One can only say that there is some developmental agency determining the form, strength, and direction of the bone plates, similar to that which determines the form, strength, and direction of the bones themselves, and which does so irrespective of the circumstance of the ossification taking place in connection with cartilage or with membrane.

I think, therefore, that much stronger evidence is required before we can assent to the view that "articular cartilage is as valuable and necessary in forming and maintaining the structure and shape of bone as periosteum is always admitted to be." Secondly, I think it is clear that the direction of the cancelli cannot be taken as an evidence of a distinction between chondrogenous and periosteal bone.

ON A TUMOUR OF THE OVARY IN THE COMMON PHEASANT. By HENRY H. SLATER, B.A., F.Z.S. (PLATE VIII.)

A HEN pheasant, found dead in a very emaciated condition, showed, on being opened, a large ovarian tumour.

This tumour, of which a drawing is given *in situ* (Plate VIII., fig. 1), measured when fresh 2·3 inches in greatest length, 1·1 in breadth, and the same in depth. It was very irregular in form, and was roughly divided into three principal lobes, which were united at their bases and were subdivided into many smaller lobes: the whole presented the general sulcated appearance of a human brain, on a small scale.

Wishing to preserve it as perfect as possible as a museum specimen, I have not weighed it.

As might be expected, there was considerable displacement amongst the internal organs from the introduction of such a large mass of diseased tissue amongst them: the kidneys, so close to the seat of the disease, were much inflamed, and were soft and flabby, especially at their upper end; the liver and pancreas were full of small white spots, which proved to be small watery cysts; and the small intestine was violently constricted at intervals.

The ovary seemed to be almost entirely absorbed; nothing resembling its usual granular appearance was visible; and the tumour rested consequently directly upon the kidneys, a fold of peritoneum alone intervening. Though no ovary was visible, the left oviduct was convoluted as much as it would be in the earlier part of the breeding season, but this of course was not healthy excitement, but due to the inflammation of the organs. The right oviduct presented its usual aborted appearance.

On making a transverse section (fig. 2) of the tumour, the interior was seen to be quite solid, and in no degree cystic or alveolar; nor was there, as might have been thought likely, any tendency to a concentric growth, but, on the contrary, bundles of fibres were seen faintly to radiate from the point of attachment of the tumour.

The minute anatomy was difficult to determine, owing to the necessity of employing a high power. There were visible (figs. 3 and 4) fat cells (by far the largest), granule cells, and nucleated cells, which I regard as resembling those found in tubercle; the last named being very numerous and irregular in shape and size. Interspersed were minute fibres (fig. 4), but these were rare; and lastly, diverging from the base of attachment of the tumour, were bundles of fibres very irregular in shape. To these is due the radiated appearance of the section (fig. 2). They are unstriated muscular fibres, and seem to be the only remains of the original ovary.

This diseased ovary is only the most conspicuous part of a general tubercular affection which pervaded the whole of the viscera: the liver, pancreas, omentum, and intestines being all distinctly more or less involved.

I was under the impression that the tumour was cancerous, from the great resemblance under the microscope to medullary cancer of the human ovary; and my thanks are due to Professor Turner, who was kind enough to suggest that the tumour was probably tubercular, the correctness of which opinion was at once verified by means of dilute acetic acid.

The specimen, as represented in fig. 1, will shortly be deposited in the Museum of the Royal College of Surgeons of England.

Note on Tubercular Disease Affecting the Common Pheasant. By A. B. Stirling, Assistant Conservator, Anatomical Museum.

As a sequel to Mr Slater's case, it may be of interest to note some observations made a few years ago.

In the year 1874 Professor Douglas Maclagan presented to the Anatomical Museum of the University the bodies of two male pheasants, in their full plumage, and a year old. He had received them for examination from the Earl of Wemyss, in whose preserves at Gosford they had been bred. During the autumn of that year many of the pheasants in those preserves had pined away and died, and it was deemed advisable to have an anatomical examination in order to determine the cause of death. The pheasants were much emaciated, but the plumage had retained its usual brilliancy. On opening the abdomen, white bodies, varying in size from a shot to a

bean, were seen in the walls of the stomach and intestine, in the mesenteric glands, kidneys, liver, and spleen. These bodies had to the naked eye the appearance of tubercular masses, and the evidence of their tubercular nature was confirmed on microscopic examination. The bronchial and tracheal glands were also enlarged, and contained a whitish material of a similar nature. It was evident, therefore, that the pheasants had died from a wide-spread tubercular change in the most important of the viscera.

ON THE PLACENTA OF THE HOG-DEER (*Cervus porcinus*). By PROFESSOR TURNER, M.B., F.R.S.

IN the month of September I received from Professor A. H. Garrod the gravid uterus and fœtal membranes of a hog-deer. The amniotic cavity had been opened and the fœtus removed; one of the fœtal caruncules was still attached to a maternal cotyledon, though the others were detached from their corresponding cotyledons. The right horn of the uterus had contained the fœtus and was much more capacious than the left.

The right and left uterine cornua each contained only two large cotyledons, whilst a fifth of small size was situated on the free crescentic border of the septum between the two cornua. The small cotyledon was $\frac{8}{10}$ths inch long, and about $\frac{3}{10}$ths inch broad; the large cotyledons were between 2 and 3 inches long, and from $\frac{3}{4}$ inch to $1\frac{1}{4}$ inch in breadth. The uterus furnishes a striking example of the paucity of cotyledons in a member of the deer tribe, and is an additional illustration of the accuracy of Professor Garrod's classification of the Cervidæ as Oligo-cotyledontophora.[1]

The cotyledons were attached to the concave aspect of the uterine cornua by broad peduncles, and possessed a succulent aspect. In each cornu one large cotyledon was situated close to the opening of the Fallopian tube, whilst the other was in proximity to the uterine septum. An injection was thrown into the uterine vessels, and not only were the cotyledons richly injected, but the vessels of the inter-cotyledonary part of the mucous membrane.

Each cotyledon formed a convex mass, and its free surface was closely studded with small openings, visible with a pocket lens, from which the villi of the chorion had been drawn. When a vertical section was made through the cotyledon the surface of section was seen to be marked by striæ which represented generally the direction of elongated tubular pits, of which the above-named openings were the mouths. The

[1] *Proc. Zool. Soc.* Jan 2, 1877.

longest pits were in the middle portion of the cotyledon, where they measured about half an inch. When these vertical sections through the cotyledon were more highly magnified the pits could be traced for some distance, but as they ran somewhat obliquely they were cut across, so that their entire length could not be traced in a single section. The pits were simple or unbranched in the greater part of their length, and did not have a series of small crypt-like depressions opening from their lateral walls such as I have elsewhere described in connection with the pits in the cotyledons of the cow.[1] To a large extent the epithelial lining of the pits had been shed, but in some places patches of cells were present, either lying loose in the pits or attached to the wall. The cells were mostly irregularly polygonal in shape, but sometimes a cell of a columnar form could be seen. The absence of the epithelial lining in so many cases was probably due to the circumstance that it had been shed along with the fœtal villi, a process which, as I have elsewhere explained, takes place during parturition both in the sheep and cow.

The pits rested on a firm basis of connective tissue, in which blood-vessels were situated before they entered the walls of the pits. In the mucosa forming the peduncle of the cotyledons some elongated tubular glands, with their contained epithelium, were readily recognised, but I did not see any of these glands penetrating the mass of connective tissue forming the basis of the cotyledon, or having any communication with the pits in the cotyledon. Blood-vessels of comparatively large size were situated in the submucous tissue of the peduncle, which gave origin to the vessels which passed into the cotyledon to form the vascular arrangements in the wall of the pits.

The mucous membrane between the cotyledons was glandular. When dissected off the submucous coat, branched and tortuous tubular glands could be seen in it with the naked eye. Under a low power of the microscope their mouths, separated from each other by well-marked intervals, could be seen to open on the smooth surface of the membrane.

The bicornuated form of the chorion was very distinct, and the left cornu was not expanded like the right. The amnion

[1] *Lectures on the Comparative Anatomy of the Placenta*, 1876, p. 63.

was limited to the right or gravid horn, but did not reach to within two inches of its free end. The allantoic sac extended from the tip of one cornu to that of the other. The allantois was not prolonged beyond the chorion into diverticula allantoidis, as in the sheep and cow. In this respect it agreed with what I saw in the rain-deer described in the last number of this *Journal;* and it is not unlikely that this may be another character, to that furnished by the difference in the number of cotyledons, between the placenta of the Cervidæ and of the hollow-horned Ruminants. The general relations of the amnion and allantois to each other in the gravid side resembled what I have described in the rain-deer.

The chorion gave origin to caruncules corresponding in number and adapted to the maternal cotyledons. Each caruncle consisted of multitudes of villi closely crowded together. They were characterised by their elongated, filamentous, cylindriform shape, and by their length, which not unfrequently exceeded half an inch. As a rule each villus gave off no branches until near its free end, when it bifurcated, and these branches in their turn often bifurcated. The villi gave off no lateral branches; but the surface of the main stem and of the branches of bifurcation was marked by a delicate fringe-like elevation of the surface of the villus, which formed an irregular network. In their filamentous form, absence of collateral branches, and close aggregation on the surface of the caruncule, the villi in the hog-deer contrasted strongly with those of the rain-deer, sheep, and cow. Their form admirably adapted them for lodgment in the elongated tubular pits in the maternal cotyledon.

As I had injected the umbilical vessels, the vessels of the villi were injected. Each villus contained an artery and a vein lying parallel to each other. Although the injection had penetrated those vessels for a considerable distance, it had not filled their entire length, so that I cannot say whether in the terminal branches of the villus they were connected together by a simple loop or by a capillary network. In several specimens, however, I saw a partially injected network of capillaries immediately subjacent to the stem of the villus.

The intercaruncular part of the chorion was highly vascular. Not only did it contain numerous branches of the umbilical

vessels, but a closely-arranged capillary plexus was situated immediately beneath the free surface. In this respect it corresponded with what I have seen in the cow, sheep, giraffe, and rain-deer, but I did not recognise polygonal areas or pocket-like depressions such as I have described in those animals.

Situated on the amniotic membrane, and projecting into the sac of the amnion, were numbers of roundish or ovoid bodies, usually smaller in size than a very small shot. They appeared to be situated on the free surface of the membrane, for they could easily be scraped off with the knife, though sometimes they seemed as if the polished membrane of the amnion were prolonged over them. They were irregularly distributed, and reached up to the amniotic covering of the cord, but were not situated on the cord. Examined microscopically, they were seen to consist of collections of squamous cells, bearing a general resemblance to the tessellated epithelium of the mouth. They were apparently due to a local hyperplasia of the epithelial cells of the amnion. They had no relation to the blood-vessels of the chorion. Both in their structure and relation to the surface of the amnion they corresponded to the well-known whitish bodies found on the amnion of the cow.

Placed in the loose tissue between the wall of the sac of the allantois and the chorion were some irregularly elongated flattened bodies, some of which were as much as $\frac{7}{10}$ths inch long. They were opaque white, hard and gritty to the touch, and could be broken up into granular particles and thin plates. When acetic acid was added, scarcely any appreciable action took place; but on the addition of hydrochloric acid, bubbles of gas were evolved with great activity. The gritty material was, without doubt, carbonate of lime; and when the earthy matter was dissolved away, the soft material left was seen to be connective tissue. These bodies had no relation to the blood-vessels of the chorion, and, owing to their flattened form, occasioned scarcely any elevation of the allantoic membrane towards the sac. These bodies are obviously homologous in position to the hippomanes in the mare (before the latter have caused absorption of the allantoic membrane, and have become free in the sac of the allantois), to the white spherical bodies described by Professor Rolleston and by myself between the chorion and allantois of the pig, and to

the flattened, oval, or subcircular bodies which Professor Owen saw in the elephant, and respecting the structure of which I have given some additional particulars on p. 27 of my *Lectures on the Comparative Anatomy of the Placenta*. The presence of earthy matter in such abundance in these bodies in the hog-deer showed that they were in process of calcareous degeneration.

THE DEVELOPMENT OF THE ORGAN OF CORTI.[1]

By URBAN PRITCHARD, M.D., F.R.C.S., *Aural Surgeon to King's College Hospital, Senior Surgeon to the Royal Ear Hospital.* (PLATE IX.)

IN a paper read before the Royal Society of London in 1876,[2] I traced out the development of this structure as far as I was then able. Having since that time been fortunate enough to succeed in filling up certain gaps in the process which has made the research more complete, I venture to think that the same might be worthy of publication.

The organ of Corti is developed from a certain number of the epithelial cells lining the rudimentary ductus cochleæ, and in this paper I propose tracing the various changes which these cells undergo as they become transformed into the organ.

The ductus cochleæ is the first portion of the cochlea to make its appearance; it starts as a bud and then as a prolongation from the vestibular labyrinth. This prolongation gradually elongates, and in so doing assumes a spiral form, so that quite at an early stage of development we find the cochlea represented by a spiral tube lined with epithelium, and surrounded by stellate embryonic tissue. The development proceeds from base to apex, both as regards the spiral tube itself and the organ of Corti contained in it; so that in the same cochlea we find the organ in several stages of development, the sections at the base showing more advanced changes than those at the apex. This tube is at first oval in section, but as development advances its shape becomes more and more triangular, as in the adult animal. The whole of the tube is at first lined by the same kind of epithelium, namely, a single layer of somewhat cuboid cells. Those lying on the floor of the ductus soon show signs of elongation, becoming more or less columnar. This change is more noticeable on the inner side (the side nearest the modiolus or axis of the spiral), and on the middle of the floor of the tube.

As this change is going on in the cells an alteration takes

[1] Read before the British Medical Association, August 1878.

[2] *Proceedings*, vol. xxiv

place in the floor itself by the sulcus of the lamina spiralis gradually making its appearance, the concavity of which is, for a considerable period of fœtal life, completely filled up by the columnar cells just mentioned; and these, besides being the tallest of all the cells, are now seen to have multiplied their nuclei three or four fold. These tall cells do not persist, but dwindle down before birth so as to become cuboid again, and merely line the sulcus of the adult animal. In the drawings taken from Kölliker in many of our text-books, the sulcus is represented as filled up with cells; this error is no doubt due to the examination of fœtal preparations only.

Just to the outer side of these taller cells may be seen five rather shorter ones: these are by far the most important cells, as they form the chief part of the organ of Corti; and therefore the changes in them must be described in detail.

I have called these the five *primary cells*, and for the sake of description have numbered them from within outwards, Nos. 1, 2, 3, 4, 5.

On referring to fig. No. 1, these five cells will be seen to have scarcely altered their columnar shape, with the exception of No. 1; this has already divided transversely into two, forming a larger upper cell and a smaller lower one. Nos. 3, 4, 5, have each a double nucleus, their original ones having divided so as to form a larger one above and a smaller one below. Cell No. 2 has still only one nucleus, which is nearer its lower end—this is the cell from which the rods are to be developed; while the other four go to form the four ciliated cells of Corti above and the cells of Deiters below. As the changes are more easily followed in these four cells (Nos. 1, 3, 4, 5), I propose dealing with them first. It is the contents of the cells which divides, the cell-wall taking no part in this division. The upper of these portions, both as regards the nucleus and its surrounding protoplasm, is larger than the lower, besides which, the outline is more marked; in fact it may be seen that while the upper cells (of Corti) soon receive a distinct cell-wall, the lower cells (of Deiters) never have a distinct outline at all. The next point to be observed is the appearance of a bud projecting from the summit of each cell of Corti: these buds after a time appear to split and thus form the four cilia, or, more correctly, the four bristles.

Most of the wall of the original cells disappears, but the outer side of the 3d, 4th, and 5th, and the inner side of the 1st, become developed into vertical fibres or bands. These will be again considered in describing the formation of the membrana reticularis.

We now come to the most interesting point—namely, the development of the rods of Corti.

On examining fig. No. 1, the 2d primary cell is seen to have altered very slightly: the nucleus is single, and has a tendency to sink to the lower end. On passing to fig. 2, this cell will be seen to have become distinctly triangular, a very peculiar shape for a columnar cell: the nucleus is quite low down, and has increased considerably in size.

Next we turn to fig. 3, and here we see a more decided change: this triangular cell has largely increased in size, especially in width at its base; the nucleus has divided into two, and between these two has appeared a vacuole or space, which is the rudimentary tunnel of the organ of Corti.

But, besides these changes, the sides of cell have become developed into rudimentary rods; the shape of these can now be distinctly made out, although they are at present very clumsy in form and not very definite in outline. On tracing the development further, as seen in fig. 4, the rods may be seen to have become much more shapely, but even yet they have not attained their perfect adult form. Fig. 4 represents the state of the organ in the newly-born kitten, and as the age of the animal advances the rods become more and more delicate in form, the shafts become finer, and the extremities gradually assume their peculiar adult shape; this change is especially noticeable in the upper extremity of the inner rod, which is quite rounded off at birth, whereas in the adult rod it is square.

The next point to be considered is the formation of that peculiar network structure which covers the rods and cells, connecting and binding them together—the membrana reticularis. Unfortunately, the development of this part is not so easily traced as that of the rods and cells, but there is no doubt that it is formed from the united tops of the primary columnar cells; in other words, from that bright band which is seen forming the surface of every layer of columnar cells. The

meshes of the network are probably produced by the absorption of the central portion of the cell tops and the thickening of the margins, in the same way as the sides of the primary cells are developed into the vertical bands or trabeculæ already alluded to; the phalanges, or long meshes, are probably formed by the fusion of two or more of the rounded meshes. The vertical bands are inseparably connected with the membrana reticularis, and, in my opinion, form part of that structure; they thus connect the membrana reticularis above with the membrana basilaris below; this lower extremity of the trabeculæ is enlarged into a sort of foot very like the lower end of the rods, and is easily detached from the membrana basilaris. The vertical bands I regard as analogous to the fibres of Müller in the retina, the former connecting the membrana reticularis with the membrana basilaris, and the latter, the inner limiting membrane with the outer.

Covering over the whole organ of Corti and the sulcus spiralis is the thick membrana tectoria: this has no definite structure, no nuclei, nor any appearance of cell formation, and is no doubt of a mucoid nature. Waldeyer considers it as a secretion from the original layer of epithelium, and I have confirmed that view by tracing it as a very thin layer lining the whole of the ductus cochleæ. It first appears as an even layer covering the cells on the floor of the rudimentary ductus cochleæ; this gradually increases in thickness, especially that portion which covers the organ of Corti itself, so that at birth, and in after life, this membrane, where it covers the organ, is very much thicker than elsewhere.

Besides the parts of the organ of Corti already referred to, there are the supporting cells of Hensen, the nuclear cells (forming the nuclear layer of Waldeyer), on the lower lip of the sulcus spiralis to the inner side of the rods, and the nerves to be considered. The supporting cells of Hensen, which form the outer boundary of the organ, and also some similar cells on the inner boundary, are merely slightly modified epithelial cells, and therefore their development requires no special consideration. The nuclear cells of the lower lip of the limbus are formed from certain of the nuclei of those very tall columnar cells with many nuclei, which in early fœtal life filled up the whole of the sulcus.

Tracing the development of the nerves is of course a very difficult matter, and at present quite beyond my powers of observation. All that can be definitely stated is that some of the filaments make their appearance very early; thus one of those which cross the tunnel of the organ may often be distinguished before the vacuole in the rod-cell has made its appearance.

To briefly summarise the whole process, it may be stated that the rods, membrana reticularis, and vertical trabeculæ are developed from the walls of the original epithelial cells, whereas the ciliated and other cells are formed from their contents; and lastly, the membrana tectoria is a secretion from the same original epithelium.

In conclusion, I may remark that the foregoing observations have been made entirely from the study of my own preparations, and that I have not had the advantage of examining the specimens of my fellow-workers in Germany. Therefore, I am unable to explain the discrepancies in our conflicting interpretations of this delicate structure, but I feel confident that my explanation of the development of the rods is in the main correct. I have entirely failed to endorse Waldeyer's[1] statement that each rod is developed from a double or twin cell. Altogether my observations lead me to confirm these of Dr Arthur Böttcher,[2] rather than those of Gottstein[3] and Waldeyer.

Explanation of Plate IX.

Fig. 1, × 300 dia.—Epithelium, primary cells, at a very early stage. (1) First or innermost cell; (2) second or rod-cell; (3, 4, and 5) outer cells.

Fig. 2, × 300 dia.—A later stage. (2) Triangular rod-cell; (1, 3, 4, and 5) dividing to form upper and lower cells.

Fig. 3, × 300 dia.—A further advanced stage. (2) Rod-cell showing rudimentary rods and the vacuole.

Fig. 4, × 300 dia.—At birth, taken from lower part of the spiral. These four figures are taken from the kitten.

[1] Stricker's *Histology*, vol. iii.

[2] *Centralblatt für die medicinischen Wissenschaften*, 1870.

[3] *Nova Acta, Leopold. Acad.* 1870.

A CASE OF HEMIPLEGIA FROM AN INJURY INVOLVING LOSS OF BRAIN SUBSTANCE IN THE MOTOR REGION OF THE CONVOLUTIONS.

By JOSEPH COATS, M.D., *Pathologist and Lecturer on Pathology in the Western Infirmary of Glasgow.*

THE following case is presented to the readers of this *Journal* as bearing on the current question of the localisation of function in the brain. The patient was under observation for a few days at the Western Infirmary, Glasgow, and the following notes were made during two examinations on the 23d and 24th of August 1878.

Alexander Maclean, aged eighteen years, sustained an injury to the head nine months ago by falling from a height of 44 feet into a quarry. He was insensible for two hours, and on recovering consciousness he was completely paralysed on the right side, and had lost the power of speech. There was a large wound on the left side of the head, which did not heal completely till six months after the accident. He lay in bed for two months, chiefly, as it appears, because of the paralysis. There is no evidence that fever existed during this period, and he seems to have taken porridge and milk, with bread, &c., with considerable relish throughout. His speech began to return about a month after the injury, and it came back gradually, being even now, as he says, imperfect. Before leaving bed he began to move the leg slightly, but was totally unable to walk till about three months after the accident. The power of walking has improved ever since, and he is now able to go a considerable distance. The arm was much later of beginning to recover, and even now he is able to do very little with it. On special inquiry he states that at various times, both before and after leaving bed, the arm and leg, but especially the latter, have jerked, but never to a great extent, and not sufficiently to throw off the clothes.

On examination as he lies in bed the most prominent feature is a very marked rigidity of the muscles both of the arm and leg. The fingers are semi-flexed, and only with considerable force can they be extended. He is at present totally unable to move the

fingers either in the way of flexion or extension, but he states that sometimes he is able to extend the fingers completely. The arm is slightly emaciated, the measurements of the fore and upper arm being half-an-inch less than those of the left side. The rigidity is not confined to the muscles of the fingers, but affects those of the wrist and elbow, and to a certain extent of the shoulder. When asked to flex and extend the arm at the elbow-joint, he does so with considerable awkwardness and slowness, and seems totally unable to extend the arm fully. He is able to move the arm at the shoulder, but with some difficulty, and he cannot raise the humerus to the horizontal position. On taking hold of the arm, and trying to raise it beyond the horizontal position, considerable resistance is experienced from the rigidity of the muscles. As to the leg, he is able while lying in bed to raise the leg and move it about freely, but is quite unable to move the toes, or even to extend or flex the foot, which is permanently kept at right angles to the leg. When asked to walk he does so with a certain halt, and the toes are slightly turned in, but there is no obvious dragging. The rigidity of the muscles in the leg and foot is also considerable, it being found difficult to move the foot either one way or other from the position mentioned above.

Sensation is perfectly preserved both in the arm and leg, and, so far as can be judged by tickling the soles and pinching the leg, ordinary reflex action is nearly normal. On the other hand, the "tendon reflex," both in the arm and leg, is much exaggerated. The slighest tap in the neighbourhood of the wrist causes a marked contraction chiefly of the extensors, the most sensitive part being over the radius. Tapping here causes the whole muscles of the external aspect of the fore-arm to contract, the result being a jerking flexion of the fore-arm on the arm, possibly with a contraction of the biceps. Tapping on the tendon of the triceps causes a distinct contraction of that muscle. There is also a localised contraction of the deltoid on tapping its clavicular insertion. On comparing the other arm, there is no distinct tendon reflex on moderate tapping anywhere, except that percussion of the clavicular insertion of the deltoid causes a slight contraction. In the right leg the tendon reflex is similarly exaggerated. The slighest tap on the patellar tendon causes a

violent jerk, and a similar strong reaction follows percussion of the tendons of the extensor proprius pollicis and tibialis posticus. On the other hand, it is very little marked in the tendo Achillis. In the other leg a firm tap on the patellar tendon produces a slight contraction just as usual, and the tendons of the extensor pollicis and tibialis posticus give no reaction. On testing the electric irritability of the muscles with Faradisation the reaction of the paralysed muscles is found to be perfectly normal.

As to speech, it is difficult to form any correct estimate, as the patient has an imperfect command of English; but he himself states that he occasionally forgets the names of things, and is satisfied that there is some defect. As noted above, speech was completely lost at first, and only began to return a month after the accident. Vision is perfect.

The left side of the head is much flattened towards the vertex, and is occupied by a longitudinal cicatrix. This cicatrix is 4½ inches in length, extending backwards from near the position of the coronal suture, and lying about an inch to an inch and a half from the vertex. In the midst of the general flattening, and crossed by the cicatrix, there is a distinct triangular gap in the skull, the fingers dipping into a depression where the substance has a doughy feel and is pulsatile, the pulsation being also very distinctly visible. This triangular gap has its base parallel to the vertex, and about an inch from it, and a thread drawn from one external meatus to the other right across the vertex passes through the middle of the gap. In order to estimate the amount of flattening of the skull, a thread is stretched along the middle line over the summit of the head from the root of the nose to the occipital protuberance, and the distance measured to the external meatus on either side. The right side is found to measure 7⅞ inches, and the left 6⅜, a difference of an inch and an eighth.

Although it is not to be understood that the area of flattening of the skull represents at all accurately the area of brain affected, and although it is difficult to refer districts on the skull to convolutions beneath, yet by a comparison with the plates in Ferrier's book on the *Functions of the Brain*, the following convolutions seem to be involved in the loss of substance. The ascending frontal convolution is obviously involved, at least in its upper two-thirds. The ascending parietal is also probably

concerned, though less markedly. There is possibly some affection of the superior parietal lobule, and of the posterior portions of the superior and middle transverse frontal convolutions. As to the function of these convolutions, it is obvious that they are all within the motor area, the arm centres being very specially involved. The area also includes certain centres which are concerned, according to Ferrier, with certain movements of the mouth, but does not reach Broca's convolution.

Remarks.—The mere narration of this case, as it was noted at the bedside, might almost stand by itself, were it not that the question naturally arises, Is there any certainty as to the exact locality of the lesion in the brain? So far as the paralysis goes it closely resembles that found in many cases in which the corpus striatum is the seat of lesion, the information obtained as to the affection of speech being hardly sufficient to localise any lesion in Broca's convolution. The nature of the injury, however, and the actual diminution in the size of the head in a particular region, render it extremely probable that the lesion is essentially one of the surface of the brain and not of the basal ganglia. Certainly the broad features of the case are sufficiently striking. Here is a young man, with an obvious flattening on the left side of the head, and the only discoverable result is a paralysis of the right arm and leg, with a history showing that the paralysis was at first much more intense and accompanied by a loss of speech. The flattening of the skull corresponds exactly to the region of the brain which has come to be recognised as motor in function.

Some attention has been, during the last few years, directed to the secondary degeneration of the spinal cord which follows on a persistent hemiplegia. It is now known that sclerosis or grey degeneration of the posterior parts of the lateral columns of the cord is a constant result of hemiplegias, due to interference with the intracranial motor centres, whether these centres be in the convolutions or in the central ganglia.[1] Now, it has become a question whether any of the symptoms occurring late in hemiplegia are to be ascribed to the secondary degeneration of the

[1] See Erb, in Ziemssen's *Encyclopædia*, English translation, vol. xiii. p. 761.

lateral columns. The rigidity of the muscles, amounting, as in our case, to actual contractures, is a late symptom in hemiplegia, and from comparison of results it seems to occur about the same time as the lateral sclerosis, which takes weeks or months to develop. The existence of contractures may be taken as a pretty sure indication of the existence of secondary descending sclerosis of the lateral columns, and the spasm probably depends in some way on the existence of this sclerosis.

The other prominent symptom in this case, the great exaggeration of the tendon reflex, is much more doubtfully related to the descending sclerosis. This exaggeration of the tendon reflex is stated by Erb to be of very frequent occurrence in hemiplegia. It is also to be remarked that in the form of spinal disease, called by Erb spasmodic paralysis, in which the lesion is almost certainly a primary sclerosis of the lateral columns, the most distinctive symptoms are rigid contractions of the muscles and increase of the tendon reflex. It is very doubtful, however, whether the exaggeration of the tendon reflex in hemiplegia is to be ascribed to the lateral sclerosis. For one thing, it seems to be an earlier symptom than the muscular spasm, although it is not an immediate consequent of the hemiplegia. I have recently met with a case which seems to me to throw some light on this matter. The case is one of spasm, occurring in paroxysms, of the muscles of the hand, leg, trunk, and face, probably due to a syphilitic lesion of the motor convolutions. The convulsive attacks vary in intensity; and while there is a persistent paralysis of a slight degree, the paralysis is very intense after the severer convulsive seizures. Now, the variable paralysis here is simply to be referred to the exhaustion of the centres from the explosive attacks, and there can be no question of secondary sclerosis of the cord. Yet in this case the tendon reflex is very distinctly exaggerated. Having only seen the case casually, I am unable to say whether the exaggeration of the tendon reflex is greater after the more severe fits; but its existence in such a case as this seems to indicate that it may be due to withdrawal of the control of the higher centres without any secondary organic changes in the cord.

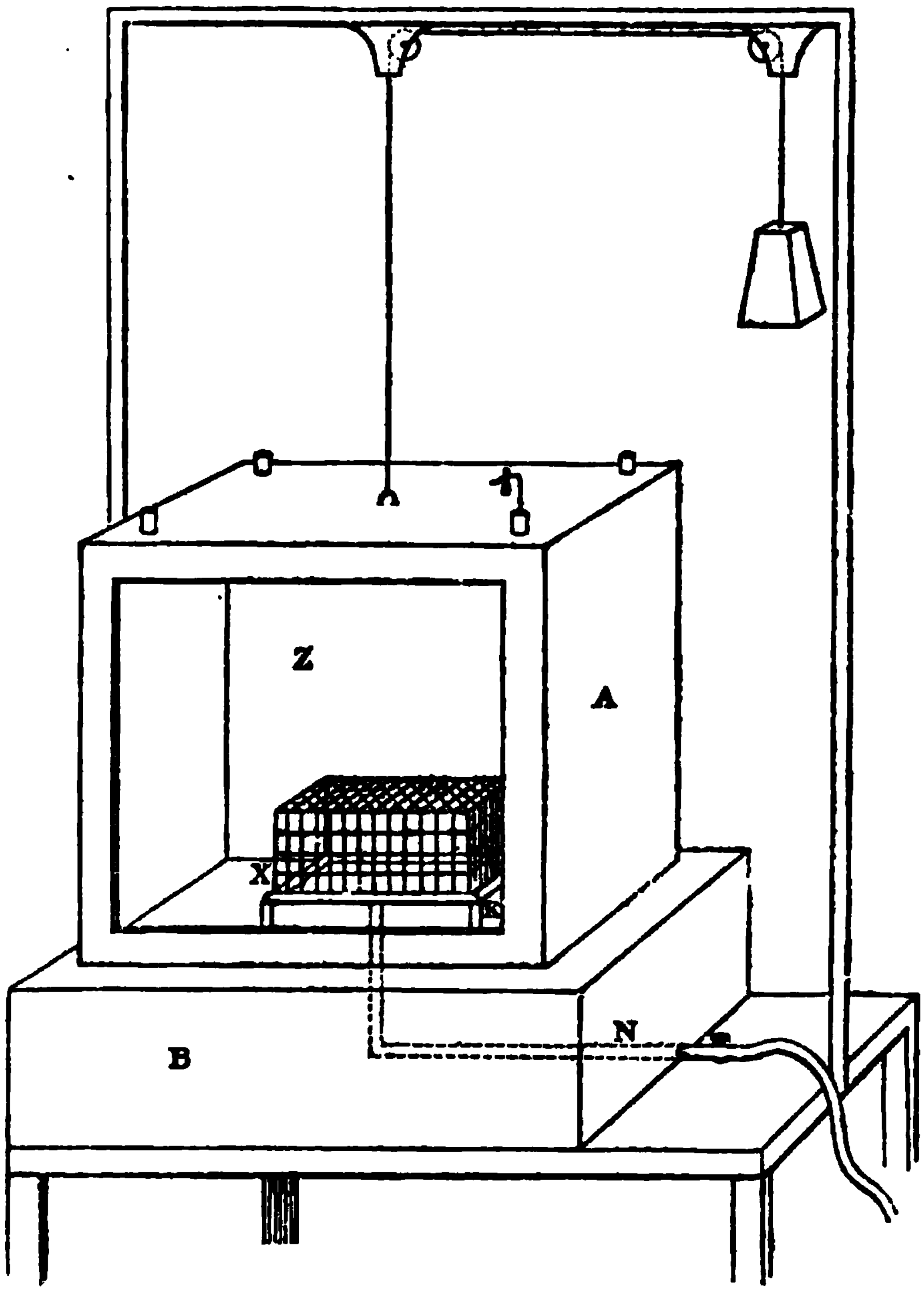
EXPERIMENTS ON THE PHYSIOLOGICAL EFFECTS OF THE INHALATION OF GASES—PHOSPHURETTED HYDROGEN. By Thomas B. Henderson, M.D., Glasgow.[1]

The investigation here detailed was suggested to me by Dr Clark, Lecturer on Chemistry at the Glasgow Royal Infirmary School of Medicine, he at the same time kindly offering to give me any chemical assistance I might require. I have also to thank Mr W. J. Fleming, Lecturer on Physiology at the same Institution, for the use of his laboratory, and for much valuable assistance and advice. The subject is one of great interest, and has hitherto, so far as I am aware, received but little attention.

The mode of experiment adopted consists in enclosing an animal in an air-tight chamber of known capacity, and of subsequently introducing into this a given quantity of the gas under investigation. The mechanical arrangement by which this is affected will be easily understood by referring to the appended diagrammatic figure, in which A represents an air-tight bottomless tin box, one side of which, Z, consists of a large pane of glass. There are four apertures in the roof, which can be accurately stoppered. The box is suspended over pulleys and counterpoised. Below it is placed a deep tin trough B, containing water; and when the box is depressed until its edge dips under the level of the contained fluid, we have simply a modified pneumatic trough. Along the bottom of the trough is led from outside a brass tube N, furnished with a stop-cock and bent at a right angle so as to rise above the level of the water and project into the depressed box. The animal is placed on a platform K inside the trough, and above the water-level; if a rat or small rabbit, in a cage X; if a larger animal, secured by ligatures. The box is then depressed until its edge dips under the water, and the gas is then introduced in one of two ways. In experiments which do not entail a very accurate estimation of the amount of gas employed, the tube N is connected with

[1] From the Physiological Laboratory of the Glasgow Royal Infirmary.

a stop-cocked tube projecting from the top of a bell-jar containing the gas, and by opening both stop-cocks and depressing the



jar in water, the gas is forced to enter the chamber A. When small quantities of gas are employed, I have found it more advantageous to use the other method. An iron tripod is placed in the trough beside the platform, and under the surface of the water, and upon it a graduated glass vessel containing water is inverted, into which the desired amount of gas is measured. The animal being secured on the platform, the box is lowered, and the gas is mixed with the contained air by withdrawing one of the stoppers from the roof of the box, passing in a curved rod, and upsetting the vessel—the rod being then rapidly removed and the stopper promptly reintroduced. When this is properly done there is no appreciable escape of gas.[1]

[1] The tripod and vessel are not represented in the figure.

In making experiments with phosphuretted hydrogen by means of the apparatus now described, it is necessary to obtain the gas without any admixture of free phosphorus, as, when so contaminated, it bursts into flame when brought into contact with atmospheric air. Pure gas was prepared for me by Dr Clark by heating in a retort a strong solution of caustic potash in alcohol along with a few pieces of phosphorus. The gas was collected by means of a pneumatic trough, and the alcoholic vapour which came over was condensed in the water.

The animals upon which I have hitherto experimented have been rats, and in one instance a rabbit, and the experiments I have completed divide themselves naturally under two heads: *first*, those showing the effects of a quantity of gas sufficient to prove rapidly fatal; *second*, the effects of smaller doses causing death more gradually. In all the experiments a *post-mortem* examination was made as soon after death as possible.

In my first experiment a strong rat was placed in an atmosphere consisting almost entirely of phosphuretted hydrogen, and death occurred in about ten minutes. An atmosphere containing one per cent. of the gas was found to prove fatal within half an hour. In the case of a large female rabbit 0·2 per cent. caused death in thirty-three minutes. In these cases the most marked symptom was that of great increase in the number of respirations. Before death, respiration became slow and laboured, and convulsions resembling those of opisthotonos occurred. A powerful effect appeared to be exercised upon the heart—both ventricles, especially the left, being found firmly contracted after death. The membranes of the brain were in all cases congested, but the brain substance was pale. In the case in which the strongest dose was administered, the effect upon the heart was most marked, and the lungs did not appear affected in any way; in the other cases there was some pulmonary congestion. I shall here give the details of the case of the rat poisoned with the strongest dose. The animal was placed under the box, and at 3.48 P.M. the gas was introduced, when it at once became very restless.

3.52. Rat had now fallen upon its side, but was able to make occasional attempts to push its nose through the wires of its cage. Respiration very rapid.

3.54. Up to this time the rat continued very uneasy; respira-

tion was very fast and apparently difficult. There now suddenly occurred movements, almost convulsive but not quite so; twitching of head and thorax apparently to facilitate respiration.

3.55. Respiration slow.

3.56. Respiration ceased for half a minute, and then recommenced very deeply and at long intervals.

3.57. Respirations = 24 per minute.

3.58. Respiration now very feeble. A sort of spasm of the whole panniculus muscle.

3.59. Rat dead.

Autopsy immediately after death.

Heart: ventricles very firmly contracted; auricles distended with dark blood.

Great veins engorged.

Lungs very bloodless.

Membranes of brain slightly congested.

Brain itself bloodless.

When small quantities of the gas were used some very curious symptoms were noted. The first symptom was always that of increased rapidity of respiration. Within a very short time after being exposed to the influence of the gas the animals began to show signs of suffering from intense irritation of the skin, scratching, and biting at it incessantly. Afterwards the creatures seemed to become drowsy and assumed a very peculiar attitude, sitting down on all-fours, the back bent upwards, and the nose pushed backwards between the fore-paws so as to bring the forehead against the floor of the cage. When in this position a rat presents a strong resemblance to a curled-up hedgehog. Striking the side of the box had the effect of rousing and apparently startling the animal, which would jump about for a few seconds, then recommence scratching and biting the skin, and finally, reassuming the hedgehog attitude, drop off to sleep again.

On making a *post-mortem* examination, the heart was found in a relaxed condition, both auricles and ventricles containing dark clots, the great veins distended with dark blood. The lungs were invariably intensely congested, as were also the liver and the membranes of the brain. The brain itself was pale. The quantity of gas used was very small—in one case in the proportion

of one to 5120; but the results were invariably the same. In two instances a small opening was left in the roof of the box so as to permit escape of gas after its admission, in each case with a fatal result and the same *post-mortem* appearances as in the other cases. My time for observation being limited, I was never able to watch an animal until death occurred, having to leave in the afternoon and return next morning, when I found the creatures dead, so that as yet I have not been able to find out the exact length of time small quantities of the gas take to kill. In no case could the characteristic odour of phosphuretted hydrogen be detected in any of the organs examined.

By way of finding out whether the gas exerts any local action on the skin, I introduced my hand into a jar containing it, and held it there for some time, but without perceiving any effect.

On examining, by means of a spectroscope, the blood of an animal which has been poisoned by phosphuretted hydrogen, the two absorption bands of arterial blood appear, and on the addition of ammonium sulphide the single absorption band is seen. The only attempt made to detect phosphorus in the organs was by means of the spectroscope in the following way:—A hydrogen bottle was fitted up with a brass burner, and the flame carefully examined with a small direct vision spectroscope. No bright lines, with the exception of the yellow sodium line in D, could be seen. Two pieces of liver and lung, taken from the body of a rat which had been poisoned in an atmosphere containing phosphuretted hydrogen in the proportion of 1 to 3200, were chopped up and added to the contents of the bottle. In a few minutes a small tongue of green-coloured flame appeared in the centre of the burning hydrogen, and on examining this with the spectroscope, two bright lines were detected in the green. A second hydrogen bottle was fitted up, and the same burner, after being carefully washed, attached. A blank experiment having been made with the hydrogen flame, a piece of the rat's liver was placed in the bottle. A green tongue of flame appeared as before, and showed three bright green lines in the spectrum. What reliance can be placed on this mode of examination in cases of phosphuretted hydrogen poisoning remains to be seen on further investigation. As a test for phosphorus it is extremely

delicate. Blondlot and Ludwig, and at an earlier date Wöhler,[1] drew attention to the fact that phosphorus, when placed along with zinc and sulphuric acid in a suitable apparatus, communicates a green tint to the interior of the hydrogen flame, and advocated the employment of this process as a test. MM. Christofle and Beilstein subsequently increased the delicacy of this method by examining the flame with the spectroscope, and detecting the three bright green lines characteristic of phosphorus. These gentlemen published a note[2] in which they gave a description of the bright lines, accompanied by a chromolithograph of the spectra of phosphorus and barium. The scale used by them to denote the position of the lines begins at the violet end of the spectrum, the line $D = 202$. The phosphorus lines are three in number and of a bright green tint, $Ph\beta$, $Ph\alpha$, and $Ph\gamma = 135$, 150, and 180 respectively. Barium gives five green lines, one of which, $Ba\delta$, corresponds exactly with $Ph\beta$, other two being very close to $Ph\alpha$ and $Ph\gamma$. ($Ba\gamma = 148$ and $Ba\alpha = 176$.) The remaining lines are $Ba\eta = 105$ and $Ba\beta = 160$. The extreme delicacy of the spectrum test was shown by MM. Christofle and Beitstein's detecting by its means the presence of phosphorus in common iron wire, a substance which, up to the date of their investigation, was not considered to contain it.

[1] Blondlot, *Journal de Chimie*, 1862, p. 528; Ludwig, *Journal de Chimie*, 1863, p. 581; Wöhler, *Annalen der Chemie und Pharmacie*, xxxix. 251.

[2] Christofle and Beilstein, *Annales de Chimie et de Physique*, quatrième série, iii. p. 281.

THREE ANATOMICAL NOTES AND TWO ANATOMICAL QUERIES.

By GEORGE ROLLESTON, M.D., F.R.S., *Linacre Professor of Anatomy and Physiology, Oxford.*

The following points of anatomy, though of no very wide significance, are nevertheless by no means devoid of interest, and are, I believe, new :—

1. The organs of Bojanus open into the pericardial space on either side, in the floor of that space at a point between the outer end of the auricle and the visceral mass in Ostrea and Pecten. It is obvious that this orifice, which in other Lamellibranchiata is drawn out into a funnel-shaped passage, is the representative of the "pyriform vesicle" of the Nudibranchiate Mollusca, for which see Hancock, *Linnæan Society's Transactions*, xxiv. p. 511 (1864).

2. To distinguish the skull of a hare (*Lepus timidus*) from that of a rabbit *Lepus cuniculus*), several points of difference may be employed. Perhaps the readiest, and, as I believe, the surest, is the greater complexity of the maxillo-turbinal bones in the latter animal. It is obvious that an animal living very usually in a subterranean atmosphere is advantaged by having that atmosphere warmed as much as possible before entering the lungs.

3. Two of the subungulate Rodents—viz., the guinea-pig (*Cavia aperea*), as shown by Mr Marshall (*Phil. Trans.* 1850, p. 151); and the agouti (*Dasyprocta aguti*)—resemble the Ungulata proper, in having but a single *vena cava superior*. They differ from these larger quadrupeds in possessing clavicles, though, it is true, incomplete ones. *Cœlogenys* also—another of the subungulate Rodents—possesses clavicles. I should be much obliged to any of the readers of the *Journal of Anatomy and Physiology* who would inform me whether *Cœlogenys, Hydrochœrus*, and *Dolichotis* have one or two *superior cavæ*, and whether the two last-named of the five *Subungulata* are really entirely devoid of clavicles.

ON THE OVUM AND PLACENTA OF THE DUGONG (*Het Ei en de Placenta van Halicore Dugong*). By PAUL HARTING, Utrecht.

(*Abstract by Professor Turner.*)

DR PAUL HARTING presented to the University of Utrecht, on the occasion of his graduation as Doctor of Philosophy, 18th February 1878, a *Thesis on the Ovum and Placenta of the Halicore Dugong*, and incorporated with it some observations on the taxonomic and phyllogenetic value of the characters furnished by the placenta. This essay is of great interest and importance, as it is the first contribution which has been made on the placentation of the Sirenia, and it fills up, therefore, a lacuna in our knowledge of the placentation of the mammalia. Dr Harting has just published his thesis, and has illustrated it with nine figures. He has provided also a French translation from the original Dutch of the more important chapters of the thesis, so as to make it more generally accessible to naturalists.

The specimen described had been recently received by the Zoological Museum of the University of Utrecht, which had obtained it from the widow of a ship surgeon. It consisted of the fœtus of a dugong along with its membranes, and had been preserved in spirit of wine for a number of years, so that the membranes were much contracted. The fœtus, a male, was 27·8 c. long, and 19 c. in girth in the region of the umbilicus, and was far from being mature. The umbilical cord was only 23 mm. long, and divided into four branches, which varied in length from 85 to 114 mm. The cord and its branches were invested by the amnion, which passed as a thin membrane from one branch to another. Each branch of the cord contained an umbilical artery and a vein.

The total length of the chorion in the constricted condition of the membrane was 33 c.; its circumference 16·5 c. Making every allowance, however, for the contraction, it would appear that the chorion was small in relation to the size of the fœtus, and that the liquor amnii was small in quantity. The surface of the chorion opposite the os uteri was smooth and formed a cæcal pouch, whilst another smooth surface was found at the opposite pole of the chorion. Except these parts all the rest of the outer surface of the chorion was covered with villi, including a pouch-like prolongation which had probably entered into the second horn of the uterus. The villi varied in length from 0·7 to 1·5 mm. They were most dense about the middle of the chorion, where the branches of the umbilical cord reached it. They extended to about 3 c. from the posterior pole, but had bare spaces amongst them for a greater distance. They extended to from 4 to 5 c. from the pole opposite the os uteri where they ended, by forming an almost annular border. No membrana caduca was on

the surface of the chorion. The placenta of the dugong is therefore diffuse and non-deciduate. The amnion was attached as far as 8 c. from the posterior, aud 4 c. from the anterior pole. The internal layer of the chorion (endochorion) was formed of the vascular layer of the allantois, and the vessels extended as far as the poles of the chorion.

More than 200 yellowish-white round or ovoid bodies were scattered irregularly over the whole inner surface of the endochorion. Those that were simple in shape varied in diameter from 0·5 to 8 mm., whilst some, formed evidently by the fusion of two or three simple bodies, were 12 mm. in diameter. Almost all were attached to the veins, a few only of the smallest to the arteries. Whilst a communication appeared to exist between the canal of the blood-vessels and the interior of these bodies, the latter were not hollow but were filled by an areolar tissue, in which were a great number of small cavities freely communicating with each other. Some small cells resembling leucocytes were in these cavities. Harting regards these bodies as diverticula from the vessels, and thinks it possible that the blood may temporarily accumulate in them when the pressure to which the liquor amnii is subjected undergoes a change.

He saw no trace of the umbilical vesicle. He considers that the placental characters of the dugong, whilst having many affinities with those of the Cetacea, yet approaches more closely to the Pachyderms.

Harting states that the first enunciation of the idea that mammals might be classified according to the differences in the placenta, was not made by Sir E. Home, to whom it is usually attributed, but by Dr G. Munniks van Cleeff, in a thesis published three years before the publication of Home's memoir. He discusses the taxonomic value of the placenta, and advances similar arguments to those put forward by Turner in several of his memoirs on the placenta, that this organ should not be taken as the dominant organ for purposes of classification. He concludes by arranging the mammalia into the following groups, which he says probably represent the series of evolutions undergone by the placenta :—

1st. Mammals without a placenta; the ovum provided with a large nutrient vitellus.—*Monotremata or Erpétodelphia.*

2d. Mammals without a placenta; nutrient vitellus small or absent; large umbilical vesicle.—*Some Marsupialia or Didelphia.*

3d. Mammals with a vitelline placenta, constituted by the umbilical vesicle only.—*Unknown.*

4th. Mammals in which the placenta is constituted by the umbilical vesicle and by the allantois.—*Some Rodentia and Insectivora, perhaps also some Cheiroptera.*

5th. Mammals in which the placenta is constituted only by the allantois.—*All the higher orders.*

Notice of New Book.

CONTRIBUTIONS TO THE PHYSIOLOGY AND PATHOLOGY OF THE BREAST AND ITS LYMPHATIC GLANDS. By C. CREIGHTON, M.B., *Demonstrator of Anatomy in the University of Cambridge.* London: Macmillan & Co., 1878.

THE real nature of carcinomatous growths, their origin and development, is a problem which has for some time engaged the attention of many eminent pathologists. Much has been done in the way of describing and classifying tumours, and important researches have been made into the mode of development and the structure of carcinomatous growths. Virchow regards cancers as arising from the transformation of connective tissue. Waldeyer, again, denies to connective tissue the power of producing epithelial cells. Characterising cancers as *atypical epithelial new formations*, he maintains that in all cases primary cancers have an epithelial origin. Others, again, make the lymphatic vessels of the affected organ, or white blood-corpuscles, the active element. These discussions, however, throw little light on the cause of carcinoma, and give us no physiological clue to their various forms, and to the degree of malignancy inherent in tumours. Now it is precisely such a clue that we find in this work.

Dr Creighton, in working at tumours of the breast, has arrived at a philosophical explanation of great value. He has succeeded in connecting the pathological with the natural processes of the breast, and to our mind he has satisfactorily proved that one is a modification of the other. His views may be thus sketched:—

The mamma is a racemose gland, with intermittent periods of function, whose acini are lined by a single layer of epithelium. In its growth or evolution during pregnancy the acini expand considerably, and again after lactation, in its so-called atrophy or involution, they shrink up as a whole, a change attended with the appearance of layers of fibrillar tissue between the acini. In the course of evolution and involution, the cells lining the acini undergo a series of changes, each generation differing from that preceding it. It is found convenient in describing the process of involution to particularise certain epithelial epochs, with the understanding that these are connected by transitional changes. When the breast has attained its fully developed condition, each acinus is paved with a single layer of polyhedric nucleated cells, with granular protoplasm. This is the milk stage. Shortly after lactation has ceased, the epithelium cells are found to contain vacuolar spaces, the nuclei being driven to the circumference of the cell. The secretion at this stage is mucoid. The next marked stage in the process of involution is

one in which the epithelium consists of nuclear cells. In the condition but one remove from the resting state large yellow granular cells are found both inside the acini and in the surrounding tissue. The fully involuted condition is characterised by deeply staining cells of about the same size as the nuclei of the fully developed epithelium. Evolution is much slower than involution, beginning with impregnation and extending up to parturition. During this period the epithelium goes through a series of changes which present a remarkable parallelism to those of involution, but in a reverse order. In both these processes the different generations of cells are in turn removed to make way for their successors, either by the lymphatic vessels of the gland or through the ducts. For a study of the first mode of removal the large yellow granular cells become of prime importance from their conspicuous character.

The sixth and seventh chapters are devoted to establishing the relation between tumours of the breast and its normal physiological changes, the conclusion drawn from a discussion of these tumours being that they are the result of a misdirection of the normal function of the gland.

The various forms of cells produced in the natural upfolding and unfolding of the mamma are found to be reproduced in the pathological processes. This is regarded as indicating an excitation of the same character with that which produces the same class of cells in the natural processes of the breast. In the case of tumours, however, the excitation remains the same over a considerable period, and there results an accumulation of the epithelial products. Further, in different parts of the same affected gland, according to the degree of excitation in these parts, we find different epithelial formations; each, however, of the same character with one occurring normally in evolution or involution. It is proper to observe that the pathological processes were studied mainly in the bitch, an animal whose long strip of breast presents peculiarly favourable opportunities for observing the tumour in its different stages. In particular, examples are given of the accumulation of yellow granular cells in the acini near tumours, occurring in several layers, or running out into long polypous growths, or again arranged column-wise in the interacinous stroma. We do not, however, find tumours built up entirely of such cells. The excitation is always sufficient to carry the cells on further, and accordingly examples are given of tumours whose cellular elements are mainly the large nuclear cells belonging to the middle period of normal evolution, also of those whose principal feature is the more advanced mucoid cell. The non-malignancy of the tumour is found to be dependent on the height to which the permanent excitation rises. In other words, the nearer the cells mainly composing the tumour approximate to the perfect epithelium of the gland, the less malignant is the tumour.

In the third chapter is developed a theory of the action of the lymphatic glands found in connection with the breast, which accounts for the disposal of the waste products, and tends to elucidate the function of lymphatic glands.

Using the large yellow granular cells as the easiest mode of following these waste products, the author traces them from the lymphatic vessels of the mamma to the lymphatic glands, and shows that there they are stripped of their superfluous protoplasm by the reticular tissue of the lymph sinus. They then for the most part pass into the lymphoid tissue, and are reduced to the condition of ordinary lymphoid cells.

Chapter eight contains the application of the above to the question of secondary infection of the lymphatic glands. When the breast is stimulated to morbid activity, resulting in a tumour, the lymphatic glands are called on to perform their part in the work of getting rid of the waste products. This they do up to a certain point and then break down. The protoplasmic bands of the lymph sinus thicken, the depuratory apparatus gets clogged, and the arrested cells overflow into the follicles. The point of failure may be regarded as the commencement of the secondary tumour. Coincident with these changes there occurs a swelling up of the lymphoid cells, which surround themselves with a zone of protoplasm, and subsequently take an active part in the formation of the tumour. So far we find only what occurs in all inflammatory affections of the lymphatic glands, and it is in the subsequent events that the various forms of disease declare themselves. Now a well-known feature of these secondary tumours is the manner in which they assimilate themselves even in minute points to the structure of the primary. The manner in which this is effected, however, is various. Thus, in one case, large pigmented cells from the primary tumour having found their way into the follicles, vacuolated, and formed the commencing acini of the tumour which was built up by a direct transformation of the lymphoid cells. In another case, the swollen parenchyma of the follicles seemed to undergo a general decay, and along certain lines nuclei grew up from the old cells by means of which the new structure was carved out. In still other cases the whole gland falls a prey to the infection, and takes on *en masse* the form of the primary tumour. It would appear, therefore, that the infection-tumour is in greatly varying proportions formed both by the cells coming from the primary tumour and by the structure secondarily affected. It is not denied, again, that the serum conveyed to the glands by the mammary lymphatic vessels may carry infecting matter.

The fourth chapter is concerned with the development of the mamma. The view generally accepted is that this is formed by an extension downwards of the rete-mucosum. According to this view, the first branches of the down-growing epidermic sac form the ducts, and the acini are in turn offshoots from these. Dr Creighton considers the secreting part of the gland to be developed from part of the same matricular tissue as the fat near which it lies, that part, namely, which has been left over after the formation of the fat. This view he supports by observation on the growth of the acini, and of the fat bodies in the kitten, and by a comparison between their developments, which brings out striking resemblances in their cells and cell groups while advancing to maturity. The ducts are formed some time before the acini, not as an outgrowth from the epiblast, however, but from the

mesoblastic tissue. A difficulty here arises. If the author's view of the manner in which the secreting part is formed be correct, why should the ducts which are the less essential part of the gland be the first to appear. This difficulty he meets by the application of Herbert Spencer's generalisation regarding direct and indirect modes of development.

Chapter five contains an attempt to trace the development of the lacteal function. It may be analysed thus.—The first part gives an account of the mammary gland in the echidna and ornithorhynchus. In these animals it consists of a number of isolated elongated lobules with an epithelial lining and central lumen, but without any visible ducts opening on the skin. The cells strongly resemble fat corpuscles, and the fully unfolded and completely involuted lobules may be respectively compared to the summer and winter conditions of the fat bodies in a frog. These facts are taken to support the view set forth in the fourth chapter. The second part gives a comparison between the mature breast unfolding with the fœtal breast developing. It is found that the generations of epithelial cells which appear in the periodical evolution of the mature gland, and which culminate in a race of cells rapidly vacuolating and forming milk, are paralleled by a succession of races in the developing gland, which culminate in cells forming a fluid product, the milk of the new-born. *The periodical evolution of the breast is a serial repetition of its fœtal development, and its fœtal development in its first period.*

ABSTRACT OF SOME PHYSIOLOGICAL MEMOIRS.

By J. Graham Brown, M.D.

On Secretory and Trophic Gland-Nerves. By R. Heidenhain. *Pflüger's Arch.* Bd. xvii. S. 1.

Starting from the fundamental fact, established in 1851 by Ludwig (*Zeitschr. f. rat. Med.* N.F. Bd. i. S. 278), that continuous irritation of the chorda tympani caused not only changes in the amount of the secretion from the submaxillary gland, but also variation in its composition, the author arrives at the hypothesis that in relation to this gland, as well as to the parotid, there exist two varieties of nerves which affect the secretion—one which influences the watery, and the other the organic, constituents of that fluid. The former of these he denominates *secretory*, and the latter *trophic* gland-nerves.

This hypothesis he supports by a large number of interesting experiments, the general conclusions of which may be briefly summed up as follows:—

The cerebral nerves which affect the secretion contain numerous secretory but few trophic fibres. On this account the secretion formed under their influence flows comparatively rapidly, and is, at the same time, proportionately poor in organic substances. The sympathetic, on

the other hand, contains numerous trophic fibres, but few or (as in the case of the parotid in dogs) no secretory fibres at all. Where the latter are completely wanting, irritation of the sympathetic produces no change in the amount of the secretion, but only chemical alteration in the gland-cells. Where they are present the amount of secretion caused by irritation of the nerve is small, but the fluid secreted is rich in organic constituents. (The submaxillary gland of the dog, the parotid of the rabbit.)

In fresh glands strong irritation of the trophic fibres causes more soluble organic matter to be produced than is capable of solution in the watery secretion caused by a simultaneous irritation of the secretory nerves. The quantity which cannot be dissolved partly passes away suspended in the secretion, which it therefore renders cloudy, and partly remains in the gland to be taken away by the secretion which continues to be poured out after the irritation has ceased.

The author further describes the difference in microscopical appearance which irritation of these two forms of nerve fibres causes in the parotid of rabbits. When the parotid under irritation of its cerebral secretory nerves secretes saliva to the amount of 12–14 c.c. it shows microscopically no difference in appearance from the unirritated gland. But if, on the other hand, it produce 2–3 c.c. under the influence of the sympathetic, the character of the cells is so greatly altered that they appear to belong to a completely different organ. The cells are very cloudy; the protoplasm has become more or less capable of being stained with carmine; the nucleus is round or oval, and usually contains sharply defined nucleoli; and, lastly, the cells are more or less diminished in size according to the duration of the irritation.

To perform this experiment in the rabbit, canulæ are inserted into the two parotid ducts, both sympathetics are cut through, and the one is irritated until 2–3 c.c. of fluid have been obtained from gland of the corresponding side. This gland is then excised and placed in alcohol to be hardened. Secretion is now produced from the parotid of the other side, either by irritation of the medulla, or better by injection of pilocarpin. This gland is also excised and hardened in the same way.

Thus, then, the microscopic examination of the parotid leads Heidenhain to the same conclusion as his former experiments, viz., that in the gland-nerves we have to do with two peculiar, specifically different varieties of fibres—the secretory and the trophic. The former merely provide for the watery secretion, their action finds no remarkable expression in the microscopic appearance of the gland; the function of the latter is to form the specific constituent of the secretion, which action the change in the gland-cells so astonishingly indicates.

On the Formation of Glycogen in the Liver. By Jaques Mayer. *Pflüger's Arch.* Bd. xvii. S. 164.

The author has made a series of experimental observations on this subject in the laboratory of Professor Leyden in Berlin. Solutions of grape-sugar were injected into a systemic vein in rabbits, and after 3–4

hours the animal was killed, the liver removed, and the glycogen estimated according to Brücke's process. He arrives at the following conclusions :—

1. Section of the spinal cord equally,—whether (*a*) between the fifth and sixth cervical vertebræ, (*b*) between the last cervical and first dorsal vertebræ, (*c*) between the second and third dorsal vertebræ,—does not prevent the grape-sugar, which has been injected into the circulation of the animal, from being retained there in part, and made use of in the tissue change.

2. Section of the cord between the fifth and sixth cervical vertebræ prevents, to a considerable degree, the formation of glycogen in the liver from the sugar which has been injected into the circulation, without at the same time in any way causing an increased secretion of sugar in the wine.

3. Section of the spinal cord between the last cervical and first dorsal vertebræ produces an increased formation of glycogen in the liver from the blood (? sugar) thrown into the circulation without causing a decrease in the amount of sugar contained in the blood.

4. Section of the cord between the second and third dorsal vertebræ causes decreased glycogen formation (in the liver) from the sugar thrown into the circulation, and produces a considerable conversion of the sugar into the tissues of the organism.

ON DIFFERENT VARIETIES OF NERVE IRRITATION. By P. GRÜTZNER. *Pflüger's Arch.* Bd. xvii. S. 215.

The author points out that there are a number of nerve irritants which act in the most different manner on the different varieties of end apparatus.

By a temperature of 45°–50° C. the centripetal nerves of the most different variety are irritated, while (with the exception of vasodilator nerves of the skin) the centrifugal nerves are not affected. The constant electric current acts in the same way.

ON THE DISTRIBUTION OF THE COLOURED BLOOD-CORPUSCLES IN THE BLOOD STREAM. By L. VON LESSER. *Du Bois Reymond's Arch.* 1878, p. 41.

In the course of this research the author estimates the relative amount of hæmoglobin in different specimens of blood (1) by means of the spectroscope ; and (2), and chiefly, by simple comparison with the naked eye of the difference in tint in concentrated solutions of blood. He arrives at the following conclusions :—

1. The estimation of the strength of colour of different specimens of blood can be as accurately carried out by the naked eye as by any other method.

2. In the afflux and efflux movements of the heart, in the aorta and its branches, as well as in the veins which empty themselves into the right side of the heart, the quantity of hæmoglobin remains constant in equal times, and under the same conditions.

3. During changes in the velocity of the arterial flow, whether occasioned by increased peripheral resistance or alteration in the number of cardiac contractions, the quantity of hæmoglobin in arterial blood remains constant.

4. The quantity of hæmoglobin in the blood stream is dependent on such changes in the tension of the vascular system as cause quantitative changes in the afflux of blood to the right side of the heart. Of these were investigated (1) those which diminish the tension and the quantity of hæmoglobin,—hæmorrhage, prolonged tying down of the animal, section of the cervical spinal cord, temporary closure of the portal vein; (2) those which raise the vascular tension and the quantity of hæmoglobin,—spontaneous (?) vascular contraction, irritation of the spinal cord, and pressing out of blood from vascular tracts in which the circulation had been interrupted for different lengths of time, whether from closure of a vein or of an artery.

5. Hæmorrhage decreases the amount of hæmoglobin, but not in proportion to the quantity of blood lost. When the hæmorrhage does not pass a certain amount, the quantity of hæmoglobin remains normal or indeed rises above that point. In fatal hæmorrhage, however, the quantity of hæmoglobin instantly falls along with the blood pressure until a point is reached incompatible with life.

6. By continuous tying down of the animal on its back the quantity of hæmoglobin in the blood remains about normal, or it shows temporary increases or decreases; the latter may be to a considerable amount.

7. Section and irritation of the spinal cord show an analogous relation between the quantity of hæmogoblin and the vascular tension as is seen in the case of hæmorrhage.

8. After ligature of the portal vein the decrease in amount of hæmoglobin in the aortic system shows itself with great rapidity. This decrease appears before the lowering of blood pressure, which follows ligature of the portal vein, has manifested itself.

9. Temporary interruption of the circulation in the lower extremities, occasioned by ligature of the abdominal aorta below the level of the renal arteries, only causes changes in the amount of hæmoglobin in the aortic current, if either a reflex vasometor irritation takes place, or if one at the same time interferes with the circulation in other tracts by ligature of the portal vein.

On a New Instrument for Recording the Movements of the Frog's Heart. By C. S. Roy, M.D. (*Verhandl. der Berl. physiol. Ges.*) *Du Bois Reymond's Arch.* 1878.

This apparatus (tonograph) consists of a cylinder of glass placed vertically, the upper opening of which is closed by means of an india-rubber stopper, through which passes a double perfusion canula, to the lower end of which is fastened the ventricle of a frog's heart. To the lower openings of the cylinder is attached a very thin, flexible, and slack membrane. Through the centre of this membrane passes a sewing needle, to the point of which is soldered a light, round, brass

plate. This plate is fastened to the membrane by means of varnish, and from the lower end of the needle is suspended a writing lever. Opening into the cylinder there are in addition two other tubes, the one of which passes through the upper stopper, while the other is carried in through the side. The latter tube is in connection with a Mariotte's flask, from which the cylinder can be filled with olive oil (the oil surrounding on all sides the frog's heart, which lies in the middle of the cylinder), while the air finds a way of escape by the former tube. Upon the straight leg of the perfusion canula is fastened a short funnel filled with diluted blood, such as is used for feeding the frog's heart. This blood runs into the heart and escapes by the other limb of the canula. If this orifice be closed, the heart becomes distended with blood, and a corresponding quantity of oil is forced back into the Mariotte's flask. If one now lowers this flask, the pressure in the cylinder becomes sub-atmospheric; the blood will therefore be sucked into the heart, but at the same time the pressure of the air will raise the membrane which closes the lower end of the cylinder with its attached lever. When the lever is raised to a suitable position the Mariotte's flask is shut off. If now the heart contracts, the column of blood is raised, and at the same time, since the contents of the cylinder are diminished, the membrane is also elevated. This movement the lever records on a revolving cylinder.

This apparatus possesses great advantages over the mercurial manometer, which was formerly used for this purpose, since the latter presents an ever-increasing resistance to the contracting heart. The instrument can be arranged to record such fine movements as those of the auricle of the frog's heart.

On the Absorption of Fat. By Johannes Gad. *Du Bois Reymond's Arch.* 1878, p. 181.

Von Brücke has shown (*Wiener Sitzungsber*, 1870) that oil, when shaken with diluted white of egg, fresh ox-bile, or, best, with a dilute solution of borax or of common salt, forms an emulsion much more readily and completely when it is impure from the presence of fatty acids than when it has been completely purified. The object of this paper is to show that, if other conditions are favourable, a perfect emulsion may be formed when the two fluids are not shaken, but are simply placed in contact.

A soda solution of suitable strength ($\frac{1}{4}$ per cent.) is placed in a watch-glass, and upon it a drop of rancid oil is deposited in such a manner as to avoid as far as possible any agitation of the fluid. The drop becomes immediately surrounded with an intensely white border, and from it radiates a milky fluid over the soda solution. The club-shaped extremities of the processes so formed become gradually cut off, and thus smaller drops are formed which, along with the original drop, float in an intensely white milky fluid, which the microscope shows to be an exceedingly fine and uniform emulsion.

The author shows, in short, among other points :—

1. That a drop of rancid oil, when simply placed in contact with an

alkaline fluid, forms as much emulsion, of the necessary fineness for absorption, as it is capable of forming when shaken up mechanically along with that fluid.

2. The power which different fats have of forming an emulsion when brought into contact with the same fluids is dependent on (*a*) the acidity of the oil, (*b*) the solubility of the soap formed from the fatty acid, (c) the tenacity of the oil.

3. The power which the same fat possesses of forming an emulsion when brought in contact with different fluids is dependent upon (*a*) the degree of alkalinity of the fluid, (*b*) its composition, in so far as this affects the solubility of the soap formed.

4. The maximum of quantity and quality of the emulsion is reached when the membrane which surrounds each small oil-drop is invisible. Under conditions which are more favourable to the solubility of the soap formed, no emulsionising takes place; and, on the other hand, where the membrane is visible the emulsion is less fine, and is rendered impure by particles of soap.

5. Common salt and ox-bile are capable of correcting conditions which are unfavourable to the formation of a good emulsion.

6. Cod-liver oil possess in a high degree, and within very wide limits, the power of forming an emulsion.

7. If there are conditions under which castor-oil, when brought into contact with alkaline fluids, forms an emulsion, these lie within very narrow limits.

Having shown that oil forms an emulsion only so long as it contains fatty acids, it is obvious that when the quantity of these acids present in any specimens of oil has been exhausted, more must be formed by the further decomposition of the oil if the whole of the oil is to be emulsionised. Brücke has shown that pancreatic juice has this action out of the body, and it is thus that during digestion the necessary quantity of fatty acids is produced.

The author further refers to the action of bile in aiding in the formation of an emulsion, and in influencing the passage of oil through capillary tubes and animal membranes (Wistinghausen). The peristaltic movement of the intestines he considers to be chiefly useful, as regards the emulsionising process, by greatly enlarging the surface of contact of the two fluids.

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OBSERVATIONS ON THE STRUCTURE OF THE BRAIN OF THE WHITE WHALE *(DELPHINAPTERUS LEUCAS)*.

By HERBERT C. MAJOR, M.D., *West Riding Asylum, Wakefield.* (PLATES X., XI., XII.)

THE death of a white whale (Beluga) at the Westminster Aquarium last summer afforded me, by the courtesy of the managers of that institution, the opportunity of which I had long been in search, and of which I gladly availed myself, of securing the brain of one of these large cetaceans for the purposes of comparative histological study. The Beluga, it may be observed in passing, is included in the genus Delphinapterus of the family Delphinidæ, or toothed-whales. It has received various names by different naturalists, as *Beluga catodon* (J. E. Grey), *Delphinus leucas* (Pallas), *Balæna albicans* (O. F. Müller); *Delphinapterus leucas*. The animal is common in the northern parts of the Polar Sea, especially off Greenland, Spitzbergen, and Nova Zembla, but is occasionally found farther south, and has even more than once been seen and captured off our own coast.[1]

With respect to the external characters of the brain, it was observed, on removing it, that it presented unusual depth relative to its length or antero-posterior diameter, and, further, that the great mass and volume of the organ were not in front but in the posterior region of either hemisphere. For the following note of

[1] For description of the animal, see *Recent Memoirs of the Cetacea*, by Professors Eschricht, Reinhardt, and Lilljeborg. Edited by Professor Flower. Also Bell's *History of British Quadrupeds*, and *Naturalist's Library—Mammalia*, vol. vi.

the general plan of the convolutions I am indebted to the kindness of Professor Turner, who has drawn it up from the examination of a photograph of the left hemisphere which I sent to him :—A well-marked Sylvian fissure was present on the outer surface of the hemisphere. The convolutions were arranged around this fissure in four successive tiers, separated from each other by three well-defined fissures which extended generally in the antero-posterior direction. On the inner surface of the hemisphere the convolutions presented considerable complexity, but they were obviously arranged in relation to the direction of the corpus callosum, and extended in the antero-posterior direction from the frontal end of the cerebrum backwards and downwards. There was evidence of a division of the convoluted mass into three successive tiers by intermediate furrows extending antero-posteriorly above the corpus callosum and the convolutions of the middle tier were in greater mass than those of either the upper or the lower tier. The convolutions of the two lower tiers reached the temporo-sphenoidal part of the hemisphere, while those of the upper tier did not extend so far down, but stopped at the occipital end of the cerebrum (Plate X.) The convolutionary arrangement, as above indicated, presented the closest similarity in both hemispheres.

The brain weights which are here given should, it must be stated, be received as approximative and not exact, mainly because the brain when weighed had already been immersed for twenty-two hours in spirit, there being also other circumstances which militated against the extreme accuracy desirable. As approximate, however, the results are interesting, and were as follows :—

Whole brain, 1746 *grammes* (62 oz.).
Cerebellum, 226 *grammes*.
Pons Varolii, 37 *grammes*.
Medulla oblongata, 6 *grammes*.

These weights bring out very conclusively what has not been alluded to, but could not escape remark even on a cursory examination of the brain, viz., the large size of the cerebellum and pons and the relative smallness of the medulla.

Passing now to the consideration of the histological structure

presented by the brain of the Beluga, the portions of the organ selected for examination, and upon which the description will be founded, as well as the method of preparation employed, should in the first place be stated. Histological examination has been limited to the right hemisphere, the left being reserved entire for the display and study of the convolutions. Of the right hemisphere the convolutions selected for microscopic examination were the following:—Two at the frontal end of the tier next the Sylvian fissure, which may be called the fourth tier; two at the frontal end and two about the middle of the tier next in order, which may be called the third tier; one at the middle of the second tier, and two at its occipital end; one at the occipital end of the first or highest tier. These several spots are, for the sake of accuracy, indicated in Plate X. fig. 1, and in the subsequent description will be alluded to as representing respectively the frontal, parietal, and occipital regions, the two most anterior spots being included together as frontal unless otherwise specialised.

The method of preparation employed for microscopic examination has been mainly that now so familiar as Lockhart Clarke's process, any detailed account of which would be here superfluous. Apart from other considerations, it was necessary that this method should be followed in the present instance, seeing that the preparations of the human organ with which it was intended to compare the cetacean structure had been so prepared. It is unfortunate, however, that from the circumstance that the present specimen had to be placed in spirit for preservation, immediately on removal from the skull, the freezing process was not available for making sections, so that this most valuable check on the appearances elicited by other methods has not been obtained.

With regard to the method of description to be followed, this also will coincide closely with that which I have generally pursued in dealing with the comparative study of the cerebral cortex. The general appearance of the cortical strata, as seen together in the different regions of the brain and under a low power, will first be briefly described, and then each layer will be taken up separately and dealt with in respect to all its constituent elements as observed under the higher powers of the

microscope. There will thus come under consideration the ultimate nature and structure of the nerve cells, their dimensions in the various layers and in different regions, the number of the cell processes, and the nature and extent of their connections. The nature of the supporting matrix or neuroglia will be examined, as also the structure of the blood-vessels and that of the white medullary substance. Finally, in the light of the knowledge thus acquired, the endeavour will be made to deal with the crucial and all-important consideration as to the structural relationship between the present specimen of the cetacean brain and the normal human cerebrum.

Viewed under a low magnifying power—by which means the most comprehensive idea of the disposition of the cortical strata is, I think, always to be obtained—the appearances presented in sections taken from the frontal, parietal, and occipital regions of the brain of the Beluga are such as will be found respectively figured in the accompanying plate (figs. 7, 8, and 9, Plate XII.) It is to be observed, in the first place, that the total depth of the cortex is decidedly shallow as compared with that of the human brain. It is also noticed that, as regards all three regions of the hemisphere to which attention is specially directed, the appearances presented are very similar. The resemblance, indeed, appears complete between the frontal and parietal regions, and nearly so as regards the occipital extremity; in the last mentioned region the more superficial nerve cells appearing merely slightly smaller and more uniform than in front. It is next seen that the nerve cells are disposed in bands or layers running parallel to each other and to the free margin of the convolution; the nerve cells, on the other hand, having their long axis in a direction vertical to the surface of the grey matter. Carrying the examination further, it is observed, in all the sections, that the first or most external cortical layer is in the form of a pale band almost destitute of corpuscles. Beneath this comes a well-defined second layer made up of closely set pyramidal nerve cells. Then comes a broader layer containing nerve cells, somewhat larger but also more scattered; while at the deepest part of the same layer, and maintaining the same relative position throughout all the windings of the grey matter is a row, single for the most part and very evenly distributed, of large

pyramidal cells easily distinguished by their size from any of the cells situated either above or beneath them. Lastly, sometimes with the appearance of a slight pale interval between it and the large cells above alluded to, comes the deepest cortical layer which immediately precedes and blends with the central white stem of the convolution.

Attention is specially directed to the appearances thus manifested under a low power, a due appreciation of which will greatly facilitate the more minute study of the various cortical layers which will now be entered upon. The accompanying lithographs, illustrative of the structural condition of the successive layers, as seen under a magnifying power of 300 diameters, will, it is hoped, allow of the description being readily followed, while at the same time rendering it possible in some instances to abbreviate it considerably.

First Layer.—The structure of the most external or *first* cortical layer (Plate XI. fig. 1) differs in no respect whatever, as far as I have been able to ascertain, from the corresponding layer of the human brain. The corpuscular elements are few in number, and consist for the most part of naked nucleus-like bodies (corpuscles of the neuroglia) and occasional cells with thread-like branches and connections—Deiter's cells—which are also usually considered to belong to the connective tissue, while here and there, at rare intervals, corpuscles are seen with characters not to be distinguished from those of the ordinary nucleated nerve cell of small size. The intercellular matrix consists, in this as in the other layers, of a retiform network of minutest fibrils and a cloudy molecular plasma. Traversing the layer in different directions run exceedingly fine nerve fibrils, as also numerous small vessels and capillaries. The structure presented by these latter constituents of the layer will be alluded to later.

Second Layer (Plate XI. fig. 2).—This layer, like the previous, conforms closely as regards structural arrangement with the corresponding stratum in the human brain. The nerve cells form a narrow band of closely set and very distinctly pyramidal bodies, the apices of which are, with few exceptions, directed towards the first layer, into which the apical processes of the cells may frequently be traced. In size, the greater number measure about ·018 mm. in length. They possess usually three or more poles, that of the apex of the cell being, as already stated, traceable into the outer-

most layer, while those from the base break up into numerous secondary branches, which are lost in the retiform matrix tissue. Occasionally, also, one or more branches uniting with the base of the cell may be traced directly backwards for a surprising distance into the deeper cortical layers, and is there lost. The cell nucleus is large and in form usually oval, and contains a well-marked nucleolus and granules. The other constituent elements of the second layer, viz., matrix or neuroglia, neuroglia corpuscles, and blood-vessels, present nothing to call for special description.

Third Layer (Plate XI. fig. 3).—The nerve cells of this layer are, as previously stated, less closely set than those of the previous stratum. They differ from them also in being generally of larger size, and in being broader and more truncated in form. The majority are multipolar, the apical processes passing up into the more superficial strata, while of the basal branches running laterally or backwards, some appear to blend ultimately with the retiform matrix, while others, pursuing an independent course, pass into the deepest cortical layer and the adjacent white matter. I have quite failed in this as in other parts of the cortex to obtain any indication of *direct* anastomosis of the cell-branches with each other. In size, these cells measure for the most part ·022–·025 mm. in length, and ·014–019 mm. in breadth. It is observed, however, that in the occipital region the average size of these cells is somewhat less than the estimate above given, a fact which, difficult as it is to prove by measurements (the difference not being considerable), is abundantly evident when the sections are compared under a low power. It is also an important fact in connection with the layer under consideration, and one upon which stress will hereafter be laid, that the nerve cells show but little augmentation in size in passing from the superficial to the deep region of the layer. It is, so to speak, quite suddenly, that, at the deepest border of the stratum, those singularly large cells occur, to which passing reference has already been made, and which have now to be more specially considered.

The striking appearance and constant position presented by these cells (Plate XI. fig. 4) might perhaps be thought to warrant their description as forming a separate layer of the cortex. It would seem more accurate, however, not to give them this pro

minence, mainly on the ground of their relatively small number, and because, although on the whole very evenly distributed, yet occasional intervals do occur in which they are not present, while at other spots they show a tendency to occur in small groups, thus breaking the continuity of the row. Actual measurement of these cells at once confirms what observation sufficed to indicate, viz., the great superiority of these cells in size over all others which the section presents to view. In length, the majority, it is found, measure as much as ·038–·055 mm. and in breadth ·011–·018 mm. The apices are always directed towards the periphery of the cortex, and each cell apex is drawn out in the form of a very coarse process, which, in its passage upwards through the superimposed layers, divides and subdivides, to be ultimately lost among the small cells of the second stratum. Several processes pass from the base of the cell laterally, while in almost every case a large branch can be traced from the same part running directly backwards into the deepest layer. Many of these cells are very long in proportion to their breadth, a peculiarity which I have come to regard as of some significance, seeing that it occurs, in my experience, much more frequently in the brain of lower animals than in the human structure. The position held by the cells under consideration, is as before stated constant, as is also their direction; the apex always directed towards the cortical surface, whether at the summit or the sides of the convolution. Between the large cells are scattered corpuscles of smaller size, and in all respects similar to those of the more superficial part of the third layer. Finally, it has to be said that these large cells are as numerous and distinct in the occipital region as in the frontal and parietal, but that in the occipital region they are of somewhat less average size, and show greater tendency to occur in groups than in other parts.

Fourth Layer (?)—Beneath the nerve cells just described, comes the pale, often ill-defined band, to which reference was made in the preliminary general consideration of the cortical layers, as seen with a low magnifying power. Its general structure is sufficiently indicated in Plate XI. fig. 5, by which it will appear that apart from the fact that they are less closely aggregated than at any other part of the cortex, the nerve cells present the usual characters. As regards size they measure

·022 mm. pretty uniformly. It should be stated, however, that some doubt is entertained in my mind regarding the actual disposition of this band of the cortex, arising from the fact that, while in some sections it is distinctly present, in other sections from the same regions its presence is doubtful. The point is one, among many others, which is not to be decided by the examination of a single specimen.

Fifth Layer.—This, the deepest cortical layer, presents also closely similar features in the various convolutions, and is readily distinguishable from the other strata. In Plate XII. fig. 6 is shown the general appearance of the cell elements, and the intervening matrix and fibres. It is observed that the cells (as in the corresponding layer in the human brain) show very commonly and very distinctly the spindle form which, however, obtains much more in certain districts of the layer than in others, and would seem to be determined in a great measure by the course of the fibres coming from the central white matter, for within the tracts of the fibres, the nerve cells in this layer always assume the spindle form, while at parts of the layer in which the fibres do not so collect, the cells are more stunted and irregular. It is doubtless also for this reason that the nerve cells, scattered here and there in the white matter of the convolution, have always more or less of the spindle form. With respect to size, many of the cells of this layer are as much as ·037 mm. in length, but they are very variable in this respect, some being much smaller. The layer is traversed by bands of fibres coming from the central white stem, and which, especially at the summit of the convolution, take a somewhat radiating course in their passage through it. This arrangement appears to be identical with that which occurs in the human brain in the same situation.

The central stem of the convolutions and the white matter of the hemisphere, generally, is composed of nerve fibrils, which, however, are here invested with a myeline covering of vessels, and of neuroglia and neuroglia corpuscles. Careful examination of the structure of the white matter, and searching comparison made with the human structure, have only given negative results as to the presence of any difference between them.

Similarly with respect to the blood-vessels—both arterioles

and capillaries—the demonstration of their structure has been as clear and distinct as could be desired, but the result has been always the same, no departure from the structure observed in the case of man (and it may be added in the case of mammals generally) being observable. As to whether any difference exists between the human and the cetacean brain with respect to the *degree of vascularity* of the organ is a point upon which I am unable at present to express an opinion, and which, indeed, from its nature, must require the comparison of several specimens aided by the process of injection. The general question here indicated—the comparative vascularity of the brain tissue—is one of great interest, but up to the present time it does not appear to have attracted that attention which its importance would seem to merit. I have reason to think it will be shown by future investigation that, as in the human brain, the cortex is more vascular than the white matter, so in the animal series the greatest vascularity of the cortex is with the most highly developed brain.

In summing up, in conclusion, the facts as to the relation between the minute structure presented by the cetacean brain, as now set forth, and that of the human cerebrum, I should wish to guard myself against being thought to deal too generally with the results afforded by the examination of a single specimen, even when conducted with some care, and, upon the whole, under favourable conditions. As far as I am aware there is no previous record of the structure of the whale's brain, nothing, therefore, by comparison with which my own results could be tested and verified. And, hence, it has been my object, by a systematic description of structure and by the delineation, as far as practicable, of the most important structural conditions, to make clear the grounds for the several statements advanced, and thus, perhaps, to render the more significant and conclusive any results which rare opportunity of procuring specimens may in future elicit.

It has been pointed out that in the brain of the Beluga, the grey cortex is of less depth than in the human cerebrum, a fact as apparent to the unaided vision as on the examination of prepared sections. Reference again has been made to the fact, and it is one which will be at once apparent on inspection of the Plates

(Plate XII.), that the structural appearances presented by the cortex of the occipital region resemble very closely that of the frontal and parietal regions—much more closely it may now be added than is the case in Man. Further, it has been shown that in the Beluga the first and second cortical layers, as also the deepest stratum and the adjacent white matter, all agree with the corresponding portions of the human cortex, not only as regards the arrangement of the nerve and other elements, but also apparently with respect to the actual nature and structure of those elements. Hence, then, to account for the peculiarities which cannot fail to arrest the notice of the practised observer, in sections of the brain of Beluga, whether taken from the frontal, parietal, or occipital regions as compared with the appearances presented by the human cortex, it is necessary to consider in the latter the space intervening between the bottom of the second cortical layer and the upper margin of the deepest layer; it is evident, by exclusion, that the relative difference or differences must depend upon variations in the structures thus bounded. Let the fact now be recalled that the most superficial, as well as the principal portion of this space in the human cortex, in the frontal and parietal lobes at least, is taken up by a broad band of pyramidal nerve cells, the cells progressively increasing in size towards the deepest part of the layer,[1] while in the occipital region the cells are very much smaller and more uniform, large pyramidal bodies being rare. I believe, then, that in the greater depth of this, the third layer of the human brain; in the greater number of its large nerve cells; and in the absence of any such special row of cells fringing its lower margin as has been demonstrated in the Beluga, the chief differences presented by this layer in man and in the Beluga are to be found. But, further, in the human cortex there comes immediately beneath the third layer a well-defined band of small, closely set, angular nerve cells, a layer which is specially distinct in the occipital region, and which is generally known as the fourth cortical layer. It will be observed that no description of such a layer has been given in the case of the Beluga, for the reason that no such layer has, after prolonged scrutiny, been discernable.[2]

[1] Meynert in Stricker's "Hum. and Comp. Histology." (*New Syd. Soc. Trans.*) vol. ii. fig. 234,

[2] Entire absence of so characteristic a layer as the *fourth* (human) should not,

Beneath the fourth layer again, and immediately preceding the deepest stratum, there is, as I believe, in the human cortex a pale separate layer.[1] Whether the layer is represented by the pale band described, and figured in the Beluga as lying between the row of large cells and the deepest stratum of the cortex, I am unable to pronounce with confidence. Seeing, however, that the layer in question in the human brain is not recognised by all histologists, I prefer in the present instances to draw no further comparison in respect to it.[2]

Such, then, are the main facts elicited by the study of the present specimen of the brain of the Beluga, and imperfect as they are, it is hoped they may be received as a first contribution towards the elucidation of what appears as yet to be an almost unexplored region of research.

EXPLANATION OF PLATES.

Plate X.

Fig. 1. Side view of the left hemisphere of the cerebrum of Beluga. S., Sylvian fissure; I. II. III. IV., the four tiers of convolutions arranged around the fissure of Sylvius. The portions of convolutions selected for microscopical examination are marked by the sign ×.

Fig. 2. The inner surface of the same hemisphere. C., Corpus callosum; S., Sylvian fissure; I. II. III., the three tiers of convolutions on the surface of the hemisphere. Both these figures are from photographs of the cerebrum.

Plate XI.

All the figures of this Plate are taken from a transverse section of a gyrus of the frontal region (marked by the sign $\times^1$ in Plate X. fig. 1), and illustrate different portions of cortical structure at this spot, under a magnifying power of 300 diam.

Fig. 1. Section through the thickness of the first cortical layer (*surface* of the layer in the drawing is *inferior*). Shows the retiform arrangement of minutest fibrils pervading the section, as also the

it is felt, be accepted unreservedly, on the strength of the present observation merely, especially as the layer is conspicuous in Apes. If it exists here, however, it is most scantily represented—this much is certain.

[1] Meynert, *loc. cit.*

[2] See Author's article, "The Histology of the Island of Reil" (*West Riding Asylum Reports*) vol. vi.

molecular plasma (*neuroglia*); several branchless *neuroglia* corpuscles, and a branching Deiter's cell; an ordinary nucleated nerve cell (?) close to capillary blood-vessel seen on the left side.

Fig. 2. Second cortical layer. Shows the small but closely-set and very distinctly pyramidal cells characteristic of this layer; apices of cells directed usually *upwards* into first layer; cells containing distinct nucleus and nucleolus. Vessel seen in transverse section to the right. Retiform matrix and neuroglia as in fig. 1.

Fig. 3. Third cortical layer. Shows multipolar nerve cells of this layer. Apices directed upwards (outwards). A clear space (lymph space ?) surrounds most of the cells. Prolongations of large cells (fig. 4) seen passing vertically upwards through the layer. Neuroglia, &c., as before.

Fig. 4. Shows a group of the large nerve cells situated at the *deepest* part of the previous (third) layer. Cells few in number but of very large size as compared with those of other layers; multipolar and the apical prolongations very coarse and prominent, sometimes dividing on issuing from the cell; well-marked nuclei and nucleoli. Lymph spaces (?), neuroglia, and vessels as before.

Fig. 5. Shows nerve-cells, &c., of the *fourth* (?) layer. Cells have about the same dimensions as those of the *third* layer, but are less numerous. Neuroglia, &c. as before. (This layer resembles the *fifth human* of Baillarger and others; it has obviously no resemblance to the *fourth* of the human cortex which appears to be unrepresented in the Beluga).

Plate XII.

Fig. 6. Shows the structure of the *fifth* (deepest) cortical layer from the same region as figured in Plate XI. Nerve cells have the *spindle* form characteristic of this layer. Fibres seen passing upward from the central white stem of the convolution. Neuroglia, neuroglia corpuscles, and capillaries shown.

Fig. 7. Section through a convolution at the posterior extremity of the occipital region (Pl. X., $\times^3$), magnified 60 diam.

Fig. 8. Section through a convolution of the parietal region (Pl. X., $\times^2$), magnified 60 diam.

Fig. 9. Section through a convolution of the frontal region (Pl. X., $\times^1$), magnified 60 diam.

In all three figs. (7, 8, and 9) the successive layers, as seen under a low power, are indicated by corresponding numbers at the margin of each figure. The row of large cells at the bottom of the third layer is, in each case, indicated by a cross. These cells in the frontal region (fig. 9) are larger than in the other regions (figs. 7, 8), but the difference as represented is exaggerated; in figs. 8 and 7 they should be somewhat larger and more conspicuous.

THE OPTIC NERVE FIBRES AND GANGLION CELLS OF THE MAMMALIAN RETINA. By George Thin, M.D. (Plate XIII.)

The isolation of the ganglion cells and optic nerve fibres of the retina, has certainly not been found by histologists to be invariably an easy task, and I can testify from experience that methods which are well fitted for the observation and study of other parts of the retina destroy the processes of the ganglion cells and the nerve fibres. Max Schultze has acknowledged this difficulty. In his article on the retina in Stricker's *Handbuch*, published in 1872, he makes the following remarks:—"Notwithstanding *the difficulty of isolating the cells in a good state of preservation*," he observes, "there are nevertheless a complete series of observations regarding long and branching processes which are given off in the same way as the processes of the ganglion cells of the central organs. The exact conditions of maceration of the retina necessary to secure this successful isolation, appear, however, not to be easy of attainment."

I am induced, therefore, to believe that the publication of a method by which I have found the isolation of these elements singularly easy, may be considered justifiable. At the same time, the description of the appearances observed, whilst engaged in studying the isolated cells, will, I hope, be of some use as a contribution to the evidence already existing regarding certain points on which histologists still hold considerably divergent opinions.

The method I have followed holds good for the retina of the cat and the sheep; but there can be little doubt that it will prove equally useful in the case of many other mammalia. My observations have been limited to the eyes of these two animals.

It is well known that if a sheep's eye be placed entire in a sufficient quantity of alcohol for twenty-four hours, and at the end of that time be laid open and the retina be then examined in glycerine, the optic nerve fibres and ganglion cells will be found more or less well preserved. But it is a matter of no small importance to regulate the strength of the alcohol, and diluted alcohol will be found more useful than strong alcohol. A mix-

ture of equal parts of methylated alcohol and water is a strength that I used for some time with such excellent results that I adhered to it during most of the time that I was engaged in examining this part of the retina; but latterly I found that, in most respects, a weaker strength secured as good preparations, and, for some purposes, produced better ones. For the preservation of the processes of the ganglion cells, mixtures of one part of methylated alcohol with two of water, and of one of methylated alcohol with three of water, are peculiarly well adapted. The fibres of the optic nerve expansion are well seen whichever of these strengths is used. They may be isolated in great numbers and for great lengths, after the bulb has been in equal parts of water and alcohol. When only a fourth strength of alcohol was employed, the nerve fibres were, unless well teased out, slightly obscured by adherent granules—probably the remains of connective substance of the layer.

When the strengths of a third and a fourth were used, the bulb was allowed to remain in the fluid for 36 or 48 hours.

Although both the ganglion cells and the nerve fibres in eyes, treated by the above methods, can be examined at once in glycerine, it may be found advantageous to subject the retina to other processes through which the hardened nerve-elements can now pass without injury. It may be placed first in water for a short time, and then may remain over night in staining fluids, and finally be examined and preserved in glycerine, or, after being stained, it may be passed through alcohol and oil of cloves and preserved in dammar-varnish. The glycerine preparations show both the fibres of the optic nerve expansion and the ganglion cells. The dammar preparations are useful as permanent specimens of the nerve fibres. In either case some careful manipulation with needles is necessary to disentangle the nerve fibres—a process which is particularly troublesome in the dammar preparations. Of all the staining fluids which I tried, I found a solution in water of aniline blue by far the best. For the nerve fibres aniline blue alone is sufficient; for the ganglion cells a double staining with aniline blue and eosin is useful.

Eyes which have been placed in alcohol, as above directed, may be preserved for a long period in glycerine without the

nerve fibres or ganglion cells suffering in the least. The effect of the glycerine by its affinity for water is to produce a complete collapse of the eyeball. The lens preserving the shape of the anterior part of the bulb, the posterior half is doubled up into the anterior half, forming a cavity at the bottom of which is the stump of the optic nerve. It is thus possible to prepare eyes at any time, and keep them ready for examination. I had excellent preparations of the optic nerve fibres and ganglion cells from the eye of a kitten, which, after being 24 hours in equal parts of methylated alcohol and water, had been kept 16 months in glycerine.[1]

In the sheep a very large proportion of the nerves are exceedingly fine, being similar to the smallest nerves in the illustration by Max Schultze at page 982 of Stricker's *Handbuch*. The varicosities, as I observed them, are for the most part exactly similar to those described, and figured by that histologist. But this was not invariably the case. The usual appearance is that shown in fig. 1, which represents a large fibre with varicosities, the whole fibre being stained uniformly by aniline blue. In fig. 2, a different appearance has been drawn. In this fibre and other similar ones which I observed, the varicosities have a special structure which I have not seen noticed before. The deeply stained fibre is continued through the centre of the varicosity, the peripheral parts of which are feebly stained, and have a thin membranous appearance.

An analogous appearance is seen in the fine fibres. In these the varicosities are of two kinds. There are numerous minute oval thickenings in the fibre which stain deeply with aniline blue, and the finer the fibre the more numerous are these thickenings. The part of the fibre between two swellings remains perfectly colourless. In some of the finest fibres the colourless thread is scarcely visible with a power of 400 diameters, the

[1] The method is one that might be used for the examination of the retina of rare animals when the eyes have to be procured from a distance. After the remarkable observation of the anastomosis of the ganglion cells of the elephant's retina by Corti, to which there has been, as yet, no parallel, it seems to me that a further examination of the retina of that animal is very desirable. The eyes of elephants in a condition suitable for such an examination are not easily procurable, but by the use of the above method available specimens might be had from India.

course of the fibre being marked by a line of deeply stained varicosities. The difference is more than one of degree, or than can be accounted for by the greater volume of the fibre at these points, and can, it seems to me, only be explained by supposing that there is accumulated in these swellings a substance which no longer at least exists in the intermediate parts of the fibre.

The varicosities on these fine fibres are seen in another form.

The fibre appears to open out for a short extent, so as to enclose a more or less elliptical or oval space. In this space a very finely granular substance can be observed. Sometimes the fibre remains perfectly straight and this space bulges out on one side like a pouch. A common form of this pouch is shown at the left extremity of fig. 4. The contents of the space do not stain by aniline blue.

I have called special attention to these varicosities which do not stain in order to describe a peculiarity which I have observed in some of them, and which I have shown in figures 3 and 5. In a few instances I have been able, as is seen in the drawing, to trace the minute fibre through the centre of the varicosity, the appearance so produced having a certain analogy to that shown in the larger fibre drawn in fig. 2.

These appearances bear directly on the question, whether the nerve fibres in the optic nerve expansion are, as they are usually described, naked axis-cylinders or whether they are not invested by a delicate membrane, but I concede that they are far from sufficient to settle it. Although the formation of varicosities takes place after death, and is in the present case determined as to its special form by the re-agents used, yet the constancy with which the same changes are observed suggests that they are determined by some structural peculiarity.

As compared with the retina of the sheep, a large proportion of broad fibres are found in the retina of the cat, and as the cat's retina has not been so much an object of study as that of the sheep or ox, I have drawn examples of the fibres which are mostly found in it, in figures 6, 7, and 8.

The ganglion cells shown in figures 9–23 have been drawn partly to show their various forms and sizes, and partly because they illustrate interesting points in connection with the cell processes.

In regard to the question as to whether all the ganglion cells have processes, I believe that preparations obtained by the methods which I have described, will settle it definitely in the affirmative. I have not observed a single cell to which there were not processes or distinct remnants of processes attached. In many of the smaller cells, however, the processes are so fine that I can easily imagine how they might completely disappear under the action of re-agents or in manipulation. In figures 14, 15, 22, and 23, I have drawn examples of such cells. An example of the now well-established dichotomous division of the process that joins the fibres of the optic nerve expansion is shown in figure 11.

I have observed appearances in a large number of cells that are only explicable on the theory that all the processes are enveloped in a connective tissue sheath, which is continuous with the surface of the cell—even the optic nerve process, which is usually seen and has been always described as straight and smooth. It is to this sheath that I attribute the granular and slightly fibrillated appearance of the large broad processes that pass outwards towards the molecular layer. Examples of this appearance in cells from the cat's retina are shown in figures 12 and 21. In figure 17 I have drawn a cell from the cat's retina, in which an empty sheath was attached to the surface of the cell. I describe this appearance as that of an empty sheath, because it differed from the usual processes in being collapsed and slightly torn. This collapsed appearance and its origin from and connection with the surface of the cell were very striking in the preparation, although they have been insufficiently reproduced in the drawing. The appearance was several times observed.

In many cells the processes were distinctly granular up to a certain point, whence an even varicose nerve fibrilla emerged, contrasting with the granular substance which lay between it and the cell. Examples of processes in this form are shown in figure 18, a drawing of a ganglion cell from the retina of the sheep. The true nerve elements in the processes of this cell are, as I believe, the varicose fibres in which the processes are continued. In the parts of the processes between the cell and the fibrillæ it is the connective tissue surrounding the fibrillæ

which is seen. In figure 14 a cell is drawn in which three processes in the form of simple nerve-fibrillæ leave the cell, a fourth process still retaining the fine granular sheath. Figure 22 illustrates the same point.

In figures 10, 12, 21 (*a*), and probably also 17 (*a*), examples are shown of the optic nerve process being covered with a sheath for some distance after it has left the cell. In figure 12 (*a*) the sheath had become detached from the fibre except at the point of origin of the latter. The torn empty sheath twisted round the root of the fibre and floated lightly in the preparation alongside of it.

In figure 19 a cell is drawn in which a fibre—to all appearance the optic nerve fibre—passes straight into the substance of the cell, the sheath in which it lies being continuous with the surface or wall of the cell. In figure 13 a cell is shown, in which the optic nerve fibre penetrated the cell and reached the nucleus, but whether it actually touched the nucleus I could not certainly make out.

Figure 9 is drawn because it is the only purely bipolar cell similar to those figured by Max Schultze (loc. cit. p. 986) which I saw in the cat's retina, amongst a considerable number of cells of very various forms which I observed. Figure 16 is drawn on account of the length of the processes isolated; and figure 20 simply in illustration of one of the characteristic forms of the cells in the cat's retina.

Explanation of Plate XIII.

Optic Nerve Fibres.

Figs. 1, 2, 3, 4, and 5, are drawings of optic nerve fibres from the retina of the sheep; figs. 6, 7, and 8 from the retina of the cat. They were all (with the exception of figs. 4 and 5) drawn by camera lucida, and are magnified 700 diameters. Fig. 4 is magnified about 300, and fig. 5 about 400 diameters; but the magnifying power in these two figures must be taken as having reference only to the larger varicosities, the fibres themselves being too fine to be accurately drawn as regards breadth.

Ganglion Cells.

Fig. 9. From the cat's retina. Bulb 48 hours in equal parts of methylated alcohol and water, and then three months in glycerine. × 260 (camera).

Fig. 10. From the cat (same retina as fig. 9). × 260 (camera).

Fig. 11. From the sheep's retina. Bulb in a mixture of one part methylated alcohol and two of water for 36 hours. × 500 (camera).

Fig. 12. From the cat (same retina as fig. 9). *a*, Sheath of optic nerve fibre. × 260 (camera).

Fig. 13. From the cat (same retina as fig. 9). Hartnack obj. 8, eyep. 3. Tube in.

Fig. 14. From sheep's retina. Bulb 36 hours in a mixture of one part methylated alcohol and two of water. Hartnack obj. 8, eyep. 3. Tube in.

Fig. 15. From the cat (same retina as fig. 9). × 260 (camera).

Fig. 16. From the cat (same retina as fig. 9). Hartnack obj. 8, eyep. 3. Tube in.

Fig. 17. From the cat (same retina as fig. 9). Hartnack obj. 8, eyep. 3. Tube in.

Fig. 18. From the sheep's retina. Bulb 24 hours in a mixture of one part methylated alcohol in two of water. The retina then removed and placed 12 hours in water. Examined in glycerine. Hartnack obj. 8, eyep. 3. Tube in.

Fig. 19. From the cat (same retina as fig. 9). Hartnack obj. 8, eyep. 3. Tube in.

Fig. 20. From the cat (same retina as fig. 9). Hartnack obj. 8, eyep. 3. Tube in.

Fig. 21. From the cat (same retina as fig. 9). *a*, Optic nerve sheath. × 260 (camera).

Figs. 22 and 23. From sheep's retina. Bulb 36 hours in a mixture of one part of methylated alcohol in two of water. Hartnack obj. 8, eyep. 3. Tube in.

ON THE MOVEMENTS OF THE IRIS. By William Ackroyd, F.I.C., &c.

Sect. I. It is well known that the movements of the iris are due to the stimulus of light, but I am not aware that any experiments have been hitherto made to determine the approximate quantity of that agent necessary to bring about this involuntary action. The usual way of observation precludes refined experimenting, it being customary to watch the iris of another person or animal whilst under the influence of varying amounts of light, or one's own iris by means of a mirror. Three methods will be described here, and I believe that one at least may afford a means of getting new data on this and other points.

Sect. II. The first and second methods depend upon the following facts:—that, if a divergent bundle of rays emanate from a small surface or hole, very near to the eye (say about 30 mm. off), this surface or hole is the apex of a cone of light whose base is the pupil; that every movement of the iris affects the area of this base, which appears as a circular luminous field; and finally, that I find these alterations of area, so easily seen, may be taken as indications of the movements of the iris.

The third method is equally simple. The lachrymal fluid on the surface of the cornea affects the image of any light source such as a lamp or star, and by refraction causes the appearance of rays to emanate therefrom.

It is obvious that the length of these rays must be regulated by the iris, this organ being nearer to the retina, hence when the pupil contracts the rays ought to shorten, and when the pupil expands the rays ought to lengthen out. Such I find to be the case.

Sect. III. *The First or Reflection Method.*—The following is the simplest form of the experiment I have been able to devise. Burnish the head of an ordinary brass pin, and place the pin up to head in a black hat. Now with one eye shut and your back to the light, bring this pin head near to the other eye so that

the light may be reflected into it from the convex surface of the pin-head.

One sees a circular luminous field, with projecting hairs at the bottom which belong to the top eyelid.[1] Globules of the lachrymal fluid also appear at each wink.

Expt. 1. Shade the light from the observing eye for a few seconds, then let the light fall on it again. Notice the alteration in area of the field of view. The field contracts, then expands slightly, and oscillates until the iris is adjusted for the amount of light falling into the eye.

Expt. 2. Observe the pin-head with the right eye for some moments, the left eye being closed. Open the left eye. The iris of the right eye is seen to move markedly, the pupil contracting. *Here the iris of the right eye is moved by the light entering the left one.*

Expt. 3. With everything as in Expt. 2, have both eyes closed and only open the right or observing eye. There is contraction of the pupil, but apparently no more marked than in Expt. 2.

Sect. IV. *The Second or Transmission Method.*—Prick a pin-hole in tin foil. Shut one eye and bring the hole within 12 mm. off the open eye.

Expts. 1 2, and 3 may readily be repeated by this method.

Expt. 4. Place green glass before the aperture and notice the size of the field, then withdraw the glass suddenly. The pupil contracts. Red glass gave the same result.

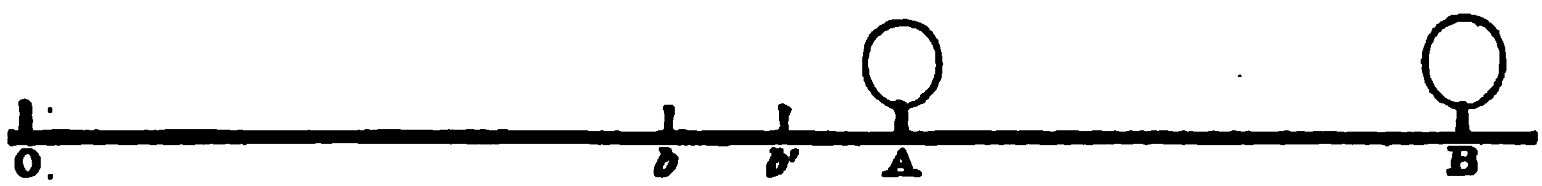
Sect. V. *The Third or Refraction Method.*—The following example will make perfectly clear the way of working here:—I am looking at a star, with the moon at full, a little to one side. From the star proceed the rays mentioned at the close of Sect. 2. Upon turning towards the moon, but still keeping my attention concentrated on the star, the rays of the latter appear to retreat into it; and upon turning from the light of the moon, the rays emanate from the star again.

Expt. 5. This is typical of about seventy other experiments I have made. The night is starless. An isolated gas lamp, with

[1] A simple method is here suggested for demonstrating to one's self the inverting action of the crystalline lens. With everything as here described, take a needle and bring it across the field of view *close* to the eyelids. *If it move downwards it appears to move upwards; if it be moved upwards it appears to come downwards.*

no houses near or any other sources of light, appears, when seen from a distance, with the usual rays emanating from it. I walk towards it slowly. At 300 yards no alteration has taken place in the rays; they appear fixed. The distance is slowly decreased, but not until I am at a distance of 16 yards do the rays perceptibly shorten—in other words, the light from this one gas lamp is incompetent to effect a movement of my iris until I am within 16 yards of it. The shortening of the rays is now rapid, for at 10 yards distance the light appears to be without them.

Expt. 6. In the preceding experiment there is a possibility that the rays may be shortened to some extent by the increase in size of the image on the surface of the cornea as we near the light. In the present experiment this objection is to some extent removed. Two gas lamps were chosen, 50 yards apart, and whilst walking towards the nearest my attention was kept exclusively on the rays emanating from the furthest one. As the first lamp is approached, the effect of its light on the iris is visible in the alteration of length of rays proceeding from the far one. Thus in the accompanying fig. A, the two lamps are A and B, and the observer stationed at O sees rays emanating from both. A is the lamp whose influence on the iris is to be tested, and B is the lamp light used as a tester. Proceeding from O towards B, a point *b* is reached at which the lamp rays of B begin to shorten, *i.e.*, the light of A affects the iris. Getting nearer still to A a point *b′* is reached, where the distant light B appears to have lost its rays.



The average of a dozen experiments gave as the value of *b*A... 14 yards, and as the value of *b′*A... 8 yards. Squaring these numbers it appears that about one-third of the light competent to contract the pupil very markedly is sufficient to start its movement.

At present, I abstain from comment, as I am continuing these experiments.

THREE CASES OF AXILLARY MAMMARY TUMOUR (WITH OBSERVATIONS). By A. H. F. CAMERON, M.R.C.S.

The first case I shall mention is that of a married woman aged thirty three. She states that she first observed a swelling under the left arm after over exerting herself at a fire, when in her alarm she seized several buckets and carried them till she was exhausted. She was then pregnant with her sixth child. After her confinement, and while nursing, milk could be squeezed from the tumour.

When examined, a soft tumour was found in the left axilla behind the fold of the pectoralis major; the mass was easily moveable and not connected with the breast of the same side. Its boundaries were difficult to define, as the edges appeared to go under some structure and elude the fingers, reminding one somewhat of a hernia. This seems to lead to the inference that there was originally a capsule or investing membrane, which had burst on the occasion mentioned above, as a result of over-exertion. This seems all the more probable as no tumour was suspected before that occurrence, and from its size when examined, and the intelligence of the patient, this seems hardly credible, unless some change then took place in its condition or surroundings.

The length of the tumour may be roughly stated at about 3 inches by 1½ in breadth. The skin over it was slightly darker in tint than that in the neighbourhood. The tumour was not painful or tender, nor had it given any trouble while suckling the last child. At the time the examination was made the patient was again pregnant, and milk could be drawn from the breast. A small orifice was found at the upper and anterior part of the tumour (but nothing like a nipple); from this a fluid could be squeezed, which, under the microscope, proved to be milk, and thus showing the true nature of the tumour.

Since the patient was under observation she has been confined, and observed during lactation that milk flowed free-

from the tumour, and that whenever the breasts were allowed to become full, the tumour swelled coincidently.

For the particulars of the following case I am indebted to Mr Bickersteth. It bears a great resemblance to the one just related, and is interesting, inasmuch as we have a microscopical examination of the tumour.

M. A. C., aged 30, unmarried. Patient states that she has enjoyed good health. Five years ago her attention was drawn to a lump the size of a walnut, which has been always painful. This seemed to swell up at times, and has steadily increased in size, very rapidly in last twelve months. It has been more painful last two years. Patient is of dark complexion, medium sized, of spare frame. Two breasts well developed, and normal. In right axilla, just posterior to anterior axillary fold, is an oval elastic swelling, equal in size to a large cricket ball. Tumour feels somewhat firmer than, but soft and compressible like a nœvus. This it was suspected it would turn out to be.

The tumour was removed antiseptically, shelling out with ease from a distinct capsule. Upon section to the naked eye appearances at once led to the belief that it was a Lipomatous fibroma, being of a greyish-white colour, soft but tough, and glistening, with oily streaks and small yellow deposits. On microscopic examination it was found to be an Adenoma, such as is found only in mammary tissue. The conclusion was, therefore, that the tumour was an Adenomatous supernumerary mamma.

Mr Bickersteth informs me that some years ago he met with a somewhat similar case in an unmarried female, thirty-three years of age. In this case a tumour about the size of the fist was present in the axilla, it had developed with the development of the breast, but it had not increased in size since the time of puberty. No operation was thought advisable in this case, and the tumour was not interfered with.

Similar cases have been frequently recorded, Simpson[1] mentions cases from Bartholin, Borelli, Lanzoni, Drejer, Robert Petrequin, and others, in which three mammæ were present, and cases from Faber, Gardeaux, Cabroli, Lamy, Tiedemann, Champion, Sinclair, R. Lee, and Moore, in which four mammæ occurred—and one

[1] *Obstetric Works*, vol. ii. p. 325.

instance in which five mammæ were seen is reported from Gorré.

Some of these cases are said to have been hereditary, especially one in which three mammæ existed in a father and in his three sons and two daughters. Mr Birkett[1] gives details of two cases in which there were four mammæ, the additional ones being situated near the axillary fold. He also mentions a case from Jussieu[2] of a breast in the groin, with which lactation was performed, and a case of four mammary glands in the male described by Dr Santesson of Stockholm. He states that in Idalium, Greece, and Egypt, this deformity is frequent, and is attributed to the effect on the imagination of contemplating the statues of Isis and Diana, but he does not give his authority for this statement.

Dr Hare[3] relates at length a case very similar to the first I have given, where the tumour was situated in the right axilla, and was not observed till after the birth of the seventh child; in this case, too, milk could be drawn from it through a minute orifice situated anteriorly, without anything like a nipple. Dr Hare quotes another case from a French source in which the mammary tumours existed in both axillæ.

Dr Handyside[4] describes a case of quadruple mammæ in a male. This paper is accompanied by a plate showing the two supernumerary nipples below the normal ones. The patient in this case was an eldest son, his next brother had the mammæ at puberty much enlarged and discharging milky fluid. The third son in this family has also quadruple mammæ. The parents are stated to be free from any abnormality, and the sons themselves to have been very strong, muscular, and masculine. But Dr Handyside saw some approach to the proportion of the female figure in the position of the umbilicus in his patient, it being situated somewhat higher than is usual.

Dr Handyside also gives on the authority of Dr Arthur Mitchell, notes of another case of quadruple mammæ in a male which was observed in the Highlands of Scotland.

If these supernumerary glands were confined to the anterior

[1] *Diseases of the Breast*, 1850, p. 24.
[2] *Lancet*, xii. 618.
[3] *Lancet*, Oct. 27, 1860.
[4] *Journal of Anatomy and Physiology*, Nov. 1872.

ABNORMAL ARRANGEMENT OF THE BRANCHES OF THE FEMORAL ARTERY. NOTE ON THE ABSENCE OF THE PROFUNDA FEMORIS.

By A. H. Young, M.B., *Senior Demonstrator of Anatomy, Owens College, Manchester.*

Amongst the numerous irregularities which have been, and are constantly being met with, in the arrangement of the branches of the femoral artery, none, so far as I can ascertain by reference to the works of Quain,[1] Henle,[2] Tiedemann,[3] Haller,[4] Theile,[5] and others, appear to have been recorded similar to one which came under my notice during the past winter session in the dissecting room of the Owens College. The subject in which it occurred was a well-developed adult male. The abnormalities were confined to the right leg, the vascular trunks in the left being normal; no noticeable arterial variation existed in other regions of the body.

The nature of the irregularity existing in the right lower limb is indicated by the following observations which are transcribed from notes made at the time of the dissection:—

The trunk of the right femoral artery is normal as regards its course and general relations. Its calibre, which is larger than that of the left femoral, is but slightly diminished at the termination of the vessel. No profunda femoris is present, whilst all the branches usually derived from this latter trunk come off directly from the femoral itself.

Of the respective branches of the femoral, however, a more detailed description is necessary. Those included under the term superficial present no deviation from their usual position and arrangement.

Of the deeper branches, from above downwards, the first is a short trunk which arises from the posterior aspect of the femoral, 1 inch below Poupart's ligament; this forms the common origin of the external and internal circumflex arteries. Of these the

[1] *Anatomy of the Arteries*, 1844.
[2] *Handbuch der Systematischen Anatomie.*
[3] *Tabulæ Arteriarum.*
[4] *Iconum Anatomicarum.*
[5] *Encyclopédie Anatomique*, Tome III. (*Traité de Myologie et d'angéiologie*).

internal takes the usual course and is distributed in the usual manner, whilst the external passes downwards and outwards beneath the rectus femoris and the anterior crural nerve, and divides into two sets of branches, which correspond to the ascending and transverse branches as normally existing. No descending branch is given off from the external circumflex, but its place is taken by a descending trunk which arises separately from the femoral, four inches below Poupart's ligament. Arising almost in common with it, but slightly to the inner side, is the third of the deep branches of the femoral. This passes internally to be distributed to the adductor muscles and the gracilis, forming a large muscular branch.

The next two branches are both given off, below the sartorius muscle, and before the femoral enters Hunter's canal. The upper of these (the largest of all the branches) arises immediately below the apex of Scarpa's triangle, and exactly 5¼ inches below Poupart's ligament. It passes inwards *under* the profunda vein, distributes muscular branches to the adductors, and pierces the adductor magnus muscle, just below the adductor brevis. From this branch the nutrient artery of the femur is derived.

The lower of the two branches now under consideration almost equals the foregoing in size, and arises 1 inch below it. Passing inwards it crosses *over* the profunda vein, perforates the adductor magnus, and terminates on the back of the thigh; before doing so, however, it furnishes muscular offsets, and also a branch of considerable size, which, descending, perforates the great adductor at a still lower level.

Jointly the branches just described, *i.e.*, the fourth and fifth of the deep branches of the femoral, appear to take the place of the profunda and its perforating branches.

Finally, an anastomotica magna is derived from the femoral in Hunter's canal. Its distribution is as usual. It is interesting to note that although the arterial abnormalities are so strikingly marked, yet the profunda vein is present and normal.

The principal features of interest in this case are such as in their practical application chiefly concern the surgeon. Taking into consideration the conditions which influence him in the selection of a site most suitable for deligation of the femoral artery, let us suppose, in a case of popliteal aneurism, it is mani-

fest how materially this must be modified in such an instance as the present one, in which the region most likely to be chosen, partly because it is usually free from large branches, is on the contrary occupied by the two largest which the parent trunk gives off.

In the event of the usual operation of ligaturing at the apex of Scarpa's triangle, being successfully accomplished under the foregoing conditions, a further point of interest presents itself, viz., that by reason of the absence of large anastomosing trunks above the point of ligature, returning pulsation in the aneurismal sac would be considerably delayed. Abnormalities of the vascular trunks of the extremities have always a special interest in respect of their surgical signification. Among such abnormalities those relating to the femoral artery and its branches occupy a most important position. More particularly, indeed, does this hold good with reference to the profunda trunk, its variations, and point of origin. It appears, therefore, advisable to record remarkable and exceptional irregularities, such as the one above described. Hence this brief communication.

NOTES ON THE TENACITY OF TISSUE. By ALEXANDER JAMES, M.D.

As a subject for investigation the purely physical properties of the tissues have always been specially attractive, and consequently our knowledge of them is very considerable. As the methods of investigation have become more plentiful and precise this knowledge has correspondingly increased in amount, and at the same time become more exact.

Of these properties that of the cohesion or tenacity of tissue has been, for long, very well known to us. By the work of Wertheim, Weber, Valentin, Matthews-Duncan, &c., we have been made well acquainted with it, and from this knowledge much valuable information, as regards the processes which take place in the animal body in health and disease, has been gained.

On examining the work of these different observers it will be found, however, that their results determine, for the most part, the *ultimate tenacity* rather than the *proof tenacity*, of the various tissues experimented upon. The distinction between these terms may be thus explained: By *ultimate tenacity* we understand the utmost pull which a portion of tissue of known dimensions sustains just before being torn asunder. By *proof tenacity* we mean the pull which such a portion can sustain without injury, or that pull, any excess of which, though not sufficient to tear it asunder at once, would ultimately do so if its application were often enough repeated or long enough continued.

Thus, while as regards the ultimate tenacity, we have only to consider the effects of the pull or weight, in estimating the proof tenacity, we must add to those the effects of time.

That the latter is the most important, in a physiological or pathological sense, is very evident, the arterial and venous urinary and other secretion pressures, all causing strains which have to be borne by the various tissues, continuously or intermittently for prolonged periods.

Whilst making some investigations into the tensile strength of

the ureter and urinary bladder in the human subject and in animals, the results of which have been published in the *Edinburgh Medical Journal*, for October and November 1878, I was unable to find, on examining the literature of this subject, any experiments in which the effects of time were taken into full consideration. To procure information on this point, I made a series of observations on the small intestines and bladders of sheep and on the ureters and bladder in the human subject, and so obtained data on which to form conclusions as regards the amount of force necessary to cause dilatation and rupture of these structures. The experiments on the intestines of sheep which I then made, although warranting the conclusions I drew from them, were not sufficiently numerous to give thoroughly accurate results. I have since repeated and extended them and the results are given in the table.

The tissue tested, viz., the small intestine of the sheep, was selected solely on account of its being most convenient for experimental manipulation.

The results obtained show that strains or weights applied to this tissue, less than the ultimate tenacity or bursting weight, in the proportion of $\frac{2}{3}$, $\frac{7}{12}$, and $\frac{1}{2}$, will cause rupture in certain definite periods of time.

The portions of intestine, each 1 foot in length, were tested by being fixed to wooden cores, by which means the weights could be conveniently applied.

On attempting to form an estimate of the average ultimate tenacity, I found that this could only be obtained approximately. This was owing to the fact that the strength of the gut varies at different parts. Thus with a piece of intestine 10 feet in length the bursting weights of the several successive portions, each 1 foot in length, presented the following variations in ounces—40, 50, 55, 53, 50, 60, 55, 59, 52, and 49 respectively. In order to obtain as accurate an estimate as possible, I therefore proceeded in the following way.

For each experiment 3 feet of intestine was taken and divided into three equal portions. By means of a spring weigher the weights required to rupture the two outer portions were obtained, and the average of these two was taken as representing the ultimate tenacity of the middle portion. To these middle portions

Table of Experiments on Proof Tenacity.

⅛			1/12			¼			
Number of Experiment.	Bursting Weights (Estimated).	Time.	Number of Experiment.	Bursting Weights (Estimated).	Time.	Number of Experiment.	Bursting Weights (Estimated).	Time.	
	oz.	min.		oz.	min.		oz.	h. min.	
1	36	¼	51	42	5¼	101	23	1·30	
2	30	½	52	42	14	102	24	·20	
3	52	½	53	44	10	103	37	3·30	
4	42	1	54	48	16	104	26	7·30	
5	40	3	55	52	49	105	24		Did not burst in 14 hrs.
6	54	1½	56	55	81	106	44	7·0	
7	60	1	57	56	14	107	45	1·30	
8	60	2	58	54	8	108	43		,, ,, ,,
9	52	5	59	49	55	109	40	2·35	
10	21	6¾	60	49	100	110	35	3·0	
11	36	10	61	44	25	111	37	12·3	
12	36	14	62	42	4	112	40	4·5	
13	47	15	63	46	23½	113	44	7·23	
14	48	5½	64	44	5	114	54	5·30	
15	56	20	65	44	120	115	56	1·47	
16	48	11	66	46	25	116	54	·58	
17	36	6½	67	54	180	117	47	1·10	
18	40	20	68	54	13	118	52	·15	
19	30	8	69	28	25	119	48		,, ,, ,,
20	48	1½	70	30	13	120	48	1·31	
21	26	1½	71	56	31	121	46	3·30	
22	29	51	72	58	7	122	44		,, ,, ,,
23	33	3	73	53	6	123	48	3·27	
24	36	½	74	47	120	124	60	·17	
25	37	¼	75	58	14	125	56	1·15	
26	37	9½	76	64	51	126	56		,, ,, ,,
27	35	1¼	77	69	11	127	58	4·3	
28	36	3¼	78	70	6½	128	60	3·4	
29	36	8	79	68	12	129	30	·41	
30	33	¾	80	63	7	130	30	11·12	
31	37	1	81	41	16½	131	34	2·53	
32	39	2	82	39	78	132	32		,, ,, ,,
33	39	50	83	37	102	133	39	·46	
34	48	¾	84	42	56	134	28	5·40	
35	39	9	85	60	8	135	26		,, ,, ,,
36	32	1	86	51	11½	136	30	·25	
37	27	27½	87	61	53	137	33	1·52	
38	28	28½	88	65	18	138	32	7·14	
39	27	22½	89	61	33	139	32	1·48	
40	27	7¾	90	62	68	140	34	2·3	
41	24	6½	91	63	150	141	34	·53	
42	26	½	92	67	51	142	34	2·42	
43	25	6½	93	70	36	143	44		,, ,, ,,
44	48	½	94	62	22	144	52	·17	
45	45	7¼	95	59	110	145	34	·18	
46	58	¾	96	53	144	146	44	·27	
47	52	½	97	52	38	147	42	2·0	
48	48	¾	98	55	34	148	44	9·5	
49	52	1	99	53	86	149	45		,, ,, ,,
50	52	36	100	53	45	150	41	8·9	
Average,		8 nearly.	Average,		44 nearly.	Average,		247 nearly.	

the various fractions of these weights were applied, and the time which elapsed between their application and the rupture of the gut noted.

As will be seen by a reference to the 10 bursting weights given above, the estimates of the ultimate tenacities obtained in this way are very uncertain. For instance, while in the first three the estimated tenacity would be 47½, the real one was 50; in the second three the estimated would be 56½ and real 50; in the last three the estimated 54 and real 52.

By making our experiments sufficiently numerous, however, we can, I think, obtain fairly trustworthy results; while, at the same time, we have explained for us the occurrence of the very great variations as to time which the table shows.

The greatest care was taken to have the condition of the portions the same as regards moisture, &c., and in every case the experiments were made within 18 hours of the death of the animal.

We thus see that with the *ultimate tenacity* or bursting weight t,

$\frac{2}{3}t$ will cause rupture in about		8	minutes.
$\frac{7}{12}t$	„	44	„
$\frac{1}{2}t$	„	247	„

With $\frac{2}{3}t$ the extremes were ¼ minute and 51 minutes. Here the estimate of the ultimate tenacity had been in the first case much too high, and in the second much too low.

With $\frac{7}{12}t$ the extremes were 4 minutes and 180 minutes—variations evidently due to similarly wide estimates.

The average obtained with $\frac{1}{2}t$ requires further explanation. As will be seen by reference to the table, in nine cases no rupture occurred even after 14 hours. I am of opinion that in each of these the estimated tenacities were considerably short of the real ones, and as I found that the condition of the gut as regards its cohesion almost always changed after a time,[1] I did not carry on the experiments longer. To compensate for those which did

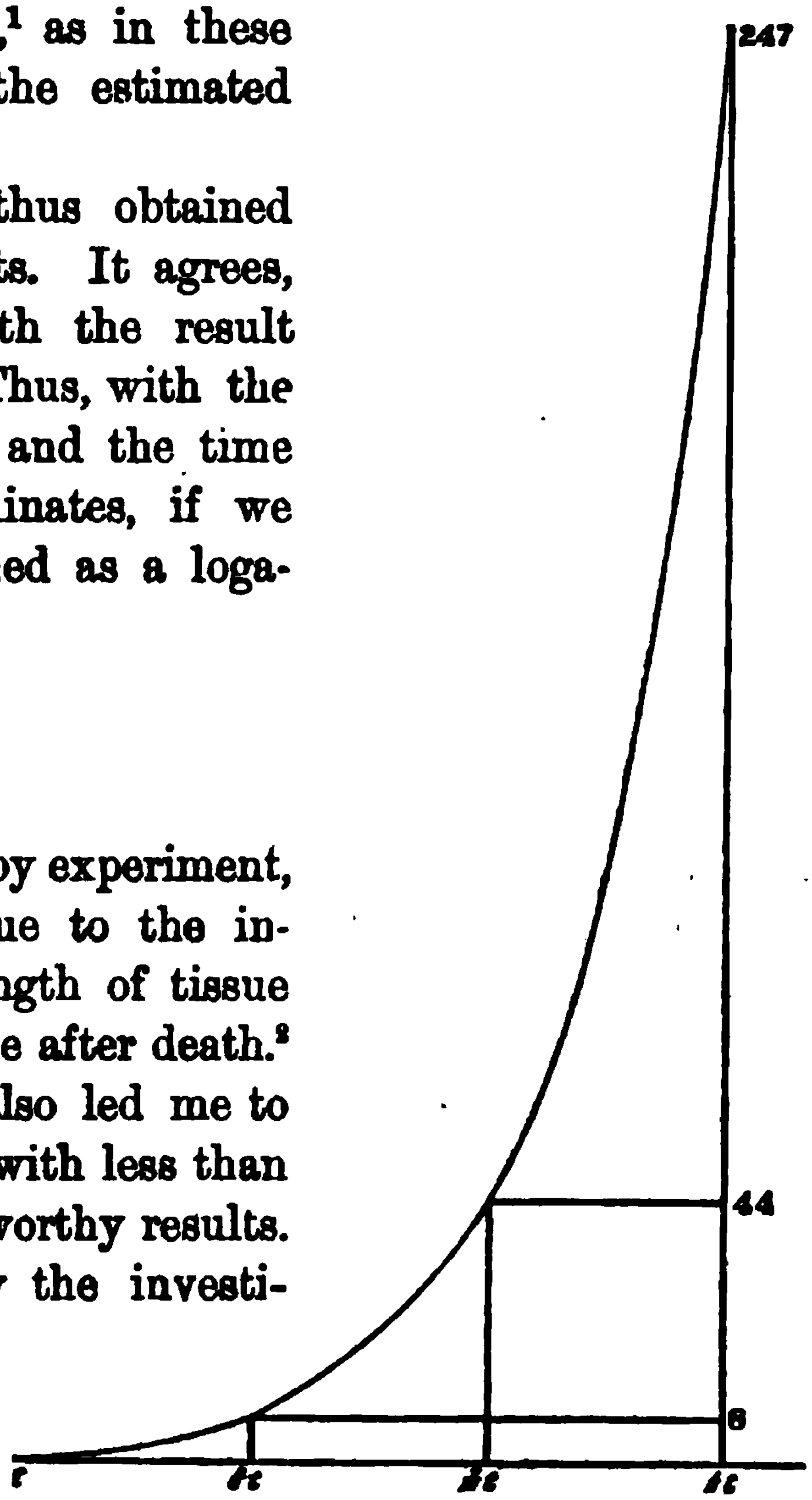
[1] Wertheim found an *increase* in the tensile strength of the fibrous tissues for some days after death.— *nnales de Chimie et de Physique, Tome XXI.*, p. 385.

not burst, I have deleted nine others which gave way in correspondingly short periods,[1] as in these we may conclude that the estimated tenacities were too high.

The average, 247, is thus obtained from only 32 experiments. It agrees, however, fairly well with the result obtained theoretically. Thus, with the weights for the abscissa and the time in minutes for the ordinates, if we regard the curve obtained as a logarithmic one, we get

$$\frac{(44)^2}{8}=242.$$

The increase obtained by experiment, viz., 247, is doubtless due to the increase in the tensile strength of tissue which occurs for some time after death.[2] This same consideration also led me to believe that experiments with less than $\frac{1}{8}t$ would not afford trustworthy results. I therefore did not carry the investigation further.



t = ultimate tenacity or bursting weight, 8, 44, and 247 = time in minutes.

[1] Marked in italics.

[2] Wertheim, *ibid.*

NOTE ON A VARIATION IN THE COURSE OF THE POPLITEAL ARTERY.—By T. P. Anderson Stuart, *Student of Medicine, University of Edinburgh.*

In May of last year, I was requested by Professor Spence to make for him a preparation of the popliteal space of the limb of a man aged 64, who had had to submit to amputation on account of gangrene of the foot, resulting from a very large popliteal aneurism. As the dissection proceeded a most striking abnormality in the course of the artery came to light, and, so far as I have been able to ascertain, it is now put on record for the first time.

The popliteal artery, after passing through the opening in the adductor magnus, instead of, as it usually does, coursing downwards and outwards towards the middle of the popliteal space, so as to lie between the two heads of the gastrocnemius muscle, passes almost vertically downwards internally to the inner head of the gastrocnemius. It reaches the bottom of the space by turning round the inner border of that head, and then passes downwards and outwards beneath it—between it and the lower end of the shaft of the femur. The inner head of the gastrocnemius arises much higher up than usual, namely, from the inner division of the linea aspera about an inch and a half above the condyle, thus leaving a considerable space between it and the condyle, over which space the artery passes. The other structures are normal. The preparation is now in the possession of Mr Spence.

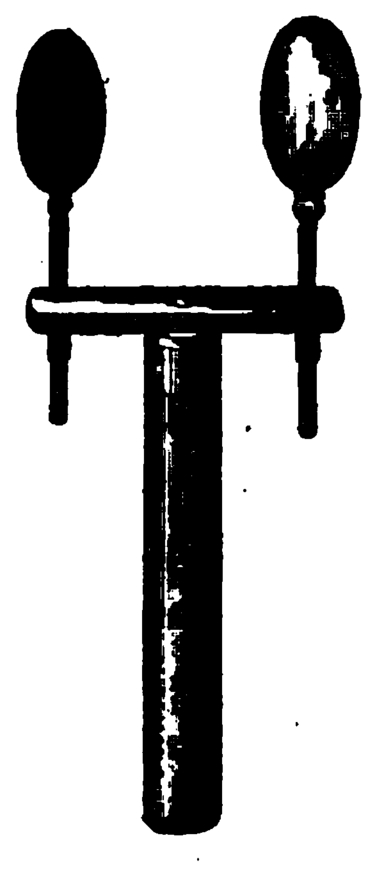
NOTE ON A METHOD FOR MEASURING THE DIAMETER OF THE RETINAL VESSELS. By J. CRAWFORD RENTON, M.B., *Assistant-Surgeon to the Eye Infirmary, Glasgow*.[1]

FOR some time I have employed the following plan for obtaining measurements of the retinal vessels:—

Using the ordinary mirror of an ophthalmoscope, along with a two-inch biconvex lens with a micrometer carefully divided into square millimetres placed 2 inches behind it, I am enabled to obtain a view of the fundus which occupies the position at which the micrometer is placed, and after a little practice the diameter of the vessels can be measured and noted. In order to facilitate working, the convex lens and micrometer have been fitted into a brass plate with a handle, and thus any one who is able to use the ophthalmoscope by the indirect method may do so with the addition of the micrometer.

The accompanying woodcut shows the form of instrument used, *a* being the convex lens, and *b* the micrometer, which was cut by Zeiss of Jena.[2] Previous to adopting the above, I made repeated experiments on rabbits, dogs, and the human subject, with a demonstrating ophthalmoscope having a micrometer placed in it, but the results were not so satisfactory.

b *a*



I have examined now a considerable number of eyes, the pupils being dilated sometimes with atropine, at other times with extract of duboisia, and also unaffected by mydriatics; and the results show that the diameter of the arteries of the retina is half a millimetre while the veins are slightly broader, being two-thirds of a millimetre.

I hope to record in a future paper the results of further observations with reference to the actions of drugs on the retinal vessels, as this method is likely to be useful in determining whether or not certain active substances affect the cerebral circulation.

[1] From the Physiological Laboratory, University of Glasgow.

[2] The instrument itself was made by M'Gillivray & Scobie, West Nile Street, Glasgow.

REMARKABLE DOUBLE MONSTROSITY OF THE HEAD. By Professor CLELAND, F.R.S., Glasgow. (PLATES XIV., XV.)

THE museum of the late Dr Montgomery of Dublin, which was purchased by the Queen's College in Galway, contains a remarkable preparation of a full grown fœtus in utero. Preserved in a greenish fluid, and with the jar encrusted with deposits, it showed little more than that the head was abnormally large, when it fell to me to direct that the solution should be changed. It was then found that the body of the child was normal, and that the head, which was greatly elongated, while it presented only one lower jaw, and pair of ears normally situated, had in front of the left ear a cyclopian eye and proboscis, in front of the right ear a normal eye with a nostril in proper relation to it, and between those very different eyes a large cranial protuberance of occipital character overhanging the mouth. From the right corner of the mouth a hare-lip cleft extended upwards, and behind this, quite to the side of the roof, the mouth communicated after the fashion of cleft palate with the nostril mentioned. The main part of the roof of the very wide mouth formed a soft spongy mass without any bone beneath the mucous membrane. I turned aside the integuments and was able to extract the whole skull intact, and restore the superficial parts to their position without injury to the external characters; and having enlarged the opening into the uterus, was enabled to reconstruct the original preparation in such a way as to exhibit, along with what had been previously shown, a great part of the characters enumerated.

It turned out, as had been expected, that the prominence over the mouth was the occipital part of a second skull, combined with that belonging to the body of the child, in such a way as to face it; and also that the spongy roof of the mouth was stretched across a gap occupying the position of foramen magnum to this second skull, while the cyclopian eye and proboscis was formed by union of adjacent parts of the two heads, and the other eye

with the corresponding nostril belonged altogether to the fully developed head.

On opening the cranial cavity it was found to be in large part occupied with fluid, and in the bottom of it were two brains only slightly united one with the other, one of them comparatively well developed, the other smaller and more imperfect.

The larger brain was that belonging to the developed child. Its hemispheres were thrown outwards by the dropsical effusion. So far as could be judged in the very soft state of the parts, the right hemisphere was normal, but the left thinned out and expanded to some extent, as if it had been pressed on by fluid within it. There was no trace of corpus callosum or fornix to be seen, nor any velum interpositum so far as I could judge, though the tentorium and falx were well developed; but between the hemispheres the corpora striata and optic thalami lay bare.

The left hemisphere of the additional brain was well formed, but not much more than a fourth of the size of the right hemisphere of the main brain, which it came in contact with and was slightly joined to. Its fellow of the right side was represented by a much smaller structure of irregular appearance, while between the two a confused mass seemed to be all that there was for the basal ganglia; for, in connection with it a cerebellum, with its plications arranged as if they all belonged to one lobe, occupied a pouch of the dura mater formed by the projection over it of a fold which acted as a tentorium, and attached to this cerebellum was an indubitable medulla oblongata, ending in an abrupt and jagged extremity below.

The highly complex double skull is in some of its details very puzzling; but it consists of cranial and face bones proper to the trunk on which it is superimposed, together with a very imperfect added set of cranial bones which have no trunk belonging to them.

The occipital, temporal, and parietal of the main skull, together with the lower jaw, are quite normal. The right frontal is turned forward in front of its eminence to meet with a bone of the added set; and on its cranial surface below it presents a short ridge, behind which it takes a small part in bounding the middle fossa basis crania.

The left frontal has a longer ridge of this sort, and takes a

larger share in bounding the middle fossa; but it is narrower, especially below; and the orbital part, which even on the right side is imperfectly separated from the frontal part, is on this side distinguished only by an overhanging ridge made by projection downward of the superficial rays of bone descending from the eminence.

The face bones of the right side appear to be perfectly normal so far as can be made out,—the malar and nasal being regularly formed, and the superior maxilla containing a complete set of rudimentary milk teeth. Also the septal cartilage of the nose comes right forward to the nostril, and is embraced inferiorly by a normal vomer. But the nasal, superior maxilla, vomer, and septal cartilage abut, not against corresponding bones of the added set, but against an occipital, which is a state of matters, so far as I know, quite unique.

The face bones of the left side are exceedingly remarkable. As low as the eye there is a symmetrical union with the appended head, for the frontal bone articulates with another frontal, having, like itself, an orbital part, separated from the frontal part by a sharp overhanging ridge; and where these two ridges meet there is, completely separate from both frontals, a little hollow ball of irregular bone, with a cartilaginous tube projecting from it—in fact an ordinary form of cyclopian proboscis, this hollow ball being all that represents the nasals and ethmoid; and immediately below this proboscis is the cyclopian eye. But below the eyeball there is nothing symmetrical. The left malar of the main skull deviates from the normal form principally in that its superior process fails quite to reach up to the frontal, and that its maxillary process is expanded, making a floor to the conjoint orbit. The left maxillary, where uncovered by the malar, lies beyond the orbit, and has no ascending process, but is traversed by an infra-orbital canal containing a superior maxillary nerve, and in front of that exhibits a squamous expansion, which lies above the mouth and abuts against the occipital bone of the appended set, the same bone against which the nostril of the other side abuts. As in the right jaw, so also in the left, a complete range of milk teeth is found. Thus on both sides the intermaxillaries are combined in the normal fashion with the superior maxillaries.

What I have termed the occipital of the added or appended set of cranial bones is in its greater part a broad scale obviously corresponding with the supra-occipital portion of an occipital, and it bridges across a large gap which was covered in by the mucous membrane of the roof of the mouth—a gap about four times as large as the foramen magnum. But at its lower part it has obviously other elements entering into its composition. A prominent tubercle, with a lateral foramen above and to one side of it, is possibly the back of the atlas, and there are two transverse ridges below this; while, projecting into the gap, and seen better from the interior, is a set of rough spicular projections on each side of a little hollow, which I have no doubt is the faint representation of a number of neural arches of vertebræ.

Between the upper part of this occipital and the right frontal of the main skull, there is one flat bone; while between it and the left frontal of the main skull there are three flat bones, all of larger size. One of these I have already said is an indubitable right frontal, with distinctly recognisable orbital part; but above the orbit it bifurcates, and filling up its bifurcation is one flat bone, while another and larger bone intervenes between it and the peculiar occipital. Some doubt may be entertained as to the nature of these last two bones to the right of the occipital, and the one bone to the left of it. The two bones to the right might be looked on as a right parietal divided into two parts, a state of matters which sometimes occurs as a rare anomaly, and in that case the bone to the left would be a left parietal. But I am led to reject this supposition, principally by taking into account that the hollow in the dura mater for the added cerebellum is not placed symmetrically on the occipital, but lies between and below the two bones to the right. The cause which displaced the cerebellum to one side may have been sufficient to displace a parietal bone from its relation to the apex of the occipital; and I think that the two bones to the right are the right and left parietal, while the bone to the left is the left frontal, coming in contact as it ought with the right frontal of the main skull.

Below the outer end of the orbital ridge of the added right frontal, and surmounting the left maxillary of the main skull, there is a bone, consisting of a scale and an orbital margin (*mxr′*),

which in its orbital part is certainly malar, while its expanded part is probably maxillary; and between this bone and the frontal and parietals there is a small scale which is very possibly the squamous (*sq.?*).

We may now turn to the interior. The occipital and temporals of the main skull, as has been said, are normal; and the great wings of the sphenoid are nearly so, except that the left is broader than the right. In front of the basi-occipital, two bones, representative of the body of the sphenoid, meet symmetrically in the middle line, and form the posterior boundary of the great supra-buccal gap already mentioned. That of the right side is in one piece, with the right orbital wing; while the left one is separated by suture from the orbital wing of its own side.

The right orbital wing presents an anterior clinoid process, with a deep notch internal to it for the internal carotid artery, and, externally to this, expands into a broad plate perforated by the foramen opticum. The inner margin of this expansion bounds the supra-buccal gap in nearly half its length; and the anterior margin gives attachment to a cartilaginous plate which extends forwards to the added occipital, is bounded on the right by the right frontal, and bears the vomer on its inferior margin. Lying against the cartilage and completing the boundary of the gap is a thin lamella of bone prolonged into a fibro-cartilaginous-looking process, which strikes across the gap towards another lamella of substance containing bone, projecting from the opposite side. What these lamellæ represent they do not offer sufficient data to enable me to suggest; but I note that between the one first mentioned and the composite bone which I have spoken of as the added occipital, there is a distinct ossification closely welded to the latter, which may well be considered as the left mastoid of the appended set.

The left orbital wing of the main skull is not a separate bone, but forms part of a composite structure, into which various elements of the added set enter. This structure is fan-shaped, consisting of two elevations and an intervening hollow converging to the point of articulation with the body of the sphenoid. The anterior clinoid process is prolonged inwards so as to complete a foramen for the left internal carotid; and outside this a foramen opticum is placed. This gives passage to the optic nerve going

to the eyeball beneath the cyclopian proboscis. I do not know what was the arrangement of the nerve. But even supposing that it came principally or even altogether from the brain belonging to the body of the child, I should yet be inclined to consider that the eye, like the proboscis, was the common property of the crania which meet at its orbit. Thus, also, I look on this foramen opticum as joint property, and the bony elevation in which it occurs as being in a similar predicament. Its further edge points towards a ridge coming down from the bone which I have designated right parietal of the added set; it overhangs an interval which may represent a sphenoidal fissure, and seems to be the free posterior edge of an orbital wing of the added set.

The hollowed part of the fan-shaped structure there can be no doubt is an alisphenoid; but the elevation beyond, which lies along the side of the supra-buccal gap, and extends to the added occipital, is of doubtful nature, and I cannot determine whether it is alisphenoidal or petrous. But where it joins the added occipital, there is on that bone a curved ridge separate from it, which may possibly be the petrous. There is no internal ear to help one, nor were there, so far as I could make out, any cranial nerves belonging to the added part of the head.

Conclusions.—In the present state of our knowledge it seems unnecessary here to enter into any discussion as to the mode of origin of double monsters. References to a large part of the literature of the subject are to be found in articles by Professor Rauber and Dr Panum, in *Virchow's Archiv.* for this and last year. But all double monsters are certainly the result of very early splitting of the embryo or the area in which it appears. This, as I have in a former article in this *Journal*[1] pointed out, is simply a phase of parthenogenesis, the multiplication of an organism by fission without the intervention of sex; and this fissiparous division, when it occurs, being confined to the embryo, the remainder of the ovum presents the obstacle which most interferes with its completion. In the present instance we are guided by the existence of the distinct second medulla oblongata to recognise that fission from below upwards as far as the head had taken place, and that from some cause the left division was

[1] May 1874, "On Double-Bodied Monsters and the Development of the Tongue."

withered in the whole extent in which it was separated from the right division, leaving no vestiges of even a spinal column, except a few irregular spicules adherent to the occipital bone. This arrest must have taken place at a very early period, as the umbilicus and whole figure of the developed body was normal; and had it not occurred we should have had a case of two children united by their foreheads.

One is struck by the circumstance that the crania are much less perfectly separated than the brains. But I believe that this is in accordance with a general rule. Thus, in a double monster which I preserved in the Galway Museum, in which the fission had been at both the caudal and the cephalic end of the embryo, the two heads were set side by side, so united that a single imperfect external ear made its appearance in front between the two, while the integuments of the two faces were continuous both above and below it. The crania had the region of the squamous part of the temporal unossified, but with a fibrous septum stretched across it, completely separating one encephalon from the other. That in such a case the integuments should be less separated than the bones, and the bones less separated than the brains, is easily understood, when it is considered that a V-shaped depression lies between the embryo brains, and that the bones lie closest to the sides of the V, and the integuments above them. In the present case the fission has been altogether from caudal to cephalic end of the embryo; but, in like manner, the junction of the not quite completely separated brains leads to a greater union of the parts around, as may be illustrated by tracing a series of outlines round the figure of a dumb-bell. I do not think that it is going too far to add, that the union or contact, in this monstrosity, of the brains by means of the anterior lobes of the hemispheres furnishes an additional proof of a point which I hold to be proved by the study of development in the chick, namely, that the hemispheres are not lateral outgrowths, but are the bifurcated extremity of the cerebro-spinal axis.

The unsymmetrical union of the two sets of cranial bones, although contrary to the rule that in double monsters the individuals are united by junction of corresponding parts in each, is not without explanation and analogy. For, though the law is

true when the individuals or parts separated by fission grow at an equal rate, it cannot be said to hold when one individual remains dwarfed as an appendage to the other; for example, when two or four additional limbs hang to the sternum; and the reason is that the close connection with the more rapidly growing individual interferes with the development of the parts of the appended individual most closely jammed up against it.

In this case the less developed or appended individual was the one to the left side. Its presence interfered so far with the development of the main skull at its point of union with it as to produce the cyclopian proboscis; while, beneath this, the upper jaw of the developed individual is driven out of shape, and the corresponding part of the appended skull is almost altogether prevented from making its appearance. But the right side of the developed skull, and the left side of the appended one, are formed from margins originally directed away from one another. Here there was no primitive union, and below the frontals there is an utter failure of that tendency which in the normal embryo brings symmetrically corresponding parts into accurate apposition along the middle line of the face and front of the body, and which, in symmetrical double monsters, effects union of corresponding parts of the two individuals.

This deviation from symmetry is, no doubt, also connected with the circumstance that not a trace exists in the appended skull of the structures formed round the chorda dorsalis, or prolonged in the mesial plane beyond it; while, on the other hand, not a half, but a complete septal cartilage of the nose, with a symmetrical vomer embracing it, belongs altogether to the developed individual, and towards this the right half of the face has been directed, nearly completing its normal connections with it.

EXPLANATION OF PLATES.

Plate XIV.

Fig. 1. View of the left side of the developed skull, and right side of the appended parts, reduced. *fr.l.*, *pa.l.*, *sq.l.*, *ma.l.*, *mx.l.*, the left frontal, parietal, squamous, malar, and maxillary; *mnd.*, lower jaw; *oc.*, occipital; *n.*, the combined nasals, with cyclopian proboscis

springing from them; *e.*, back part of the sclerotic left attached; *pa.r'.*, *pa.l'.*, *fr.r'.*, *oc'.*, right and left parietal, right frontal and occipital of the appended set; *sq.?*, probably the right squamous; and *mxr'.*, the right maxillary and malar of the appended set, in the form of one bone.

Fig. 2. View of the base, and of the right side of the developed skull, with the appended parts in front of it. The letters on the same principle as in fig. 1.

Plate XV.

Fig. 3. Interior of the base. Most of the letters as before. *orb.r.*, right orbito-sphenoid; *sp.*, body of the sphenoid in two lateral parts; *orb.d.*, double orbito-sphenoid common to the main skull and appended set of bones; *al.r'.*, appended right alisphenoid, forming one fan-shaped bone with the preceding; *vrt.*, process representing vertebræ of appended fœtus; *vo.*, vomer; *ce.*, recess in the dura mater for the cerebellum.

Fig. 4. Reduced view of the brain from above, lying *in situ*; *f.*, falx cerebri; *h.r.* and *h.l.*, right and left hemispheres of the principal brain, with the corpora striata and optic thalami between them; *h.l'.*, left hemisphere of appended brain; *c'.*, cerebellum and amorphous masses representing the right hemisphere and basal ganglia of appended brain.

Fig. 5. Reduced view of the brain from below after removal; *c*, cerebellum; *mo.*, medulla oblongata; *c'.* and *mo'.*, cerebellum and medulla oblongata of appended brain; *h.r.*, *h.l.*, right and left hemispheres of the principal brain; *h.l'.*, left hemisphere of appended brain.

FURTHER OBSERVATIONS ON THE FORMATION OF THE PLACENTA IN THE GUINEA-PIG. By C. CREIGHTON, M.D., *Demonstrator of Anatomy, Cambridge University.* (Plate XVI.).

IN a former paper on the formation of the placenta in the guinea-pig (this *Journal*, vol. xii. 1878), I described, in the fifth and concluding section, the remarkable secondary or additional placental organ that grows up in the form of a semicircle of villi or cotyledons in an interval at the back of the discoid placenta. The dual character of the guinea-pig's placenta was first clearly described by Ercolani in the memoirs of the Bologna Academy of Sciences for 1876. According to that author, the placenta of the guinea-pig contains both the ordinary rodent type and the type of the ruminant. Having, in the earlier sections of my former paper, treated of the formation of the discoid placenta from the histogenetic point of view, I wrote, as regards the secondary or cotyledonary part of the organ—"To say that this is a distinct type of placenta introduced into the middle of the ordinary rodent placenta is naturally a mere form of words. Its origin can be referred to a continuation of those adaptive processes by which the discoid placenta was formed out of the primitive decidual tissue." A description of these adaptive changes followed (p. 584), which appears to me to be substantially accurate. The illustrations of the paper did not, however, extend to that section, and I here return to the subject in order to introduce the figures that were wanting, and, at the same time, to supplement the account of the adaptive changes to which the cotyledonary organ owes its origin. Further, the formative processes in the deeper layers of the guinea-pig's uterus are somewhat unexpectedly found to supply a physiological type for the cellular phenomena that are characteristic of tubercles and certain kinds of granulations. Both the periodical sexual process, and the pathological processes exemplify that somewhat feeble or imperfect vaso-formative activity of tissue, which is associated with the production of giant-cells. I shall, for con-

venience, give my observations on that subject in the paper that follows this, under a separate title.

The occurrence of both the ordinary rodent type, and (according to Ercolani), the ruminant type of structure in the single placental organ of the guinea-pig is a subject whose interest and instruction cannot be readily exhausted. I have here to limit myself strictly to the histogenetic processes out of which the secondary or cotyledonary placenta arises. The cotyledonary placenta is found to have assumed, at an early period of gestation, the characteristic form of a very regular semicircle of villous processes projecting with free ends into a clear space at the back of the discoid placenta (see fig. 14 of my former paper). This villous fringe has arisen, as it were, in the midst of the thick pedicle that attached the discoid body to the uterine wall. The blood-sinuses passing to the discoid organ enter the latter at its sides, and the central interval of the pedicle is the space (filled by gelatinous chorionic tissue and fœtal blood-vessels), in which the free ends of the villous outgrowths lie. Although this secondary or additional portion of the placenta is widely different in appearance from the earlier, it owes its origin, as I have already observed, to a continuance of these vaso-formative processes that resulted in the building up of the discoid body. There is no break in the continuity of the histogenetic process; but there is a more or less abrupt break in the continuity of the matrix tissue.

The discoid body is formed by the adaptation of the rich and succulent perivascular cells of the sub-epithelial region to become the formative cells of a new system of vessels, superseding the original capillaries of that region. The new vessels have thick walls of nucleated protoplasm, and their terminal or capillary loops form ridges or bud-like outgrowths of spongy substance (see section 4 of former paper). These adaptive changes proceed from the epithelial surface to the deeper parts, and at length the circular muscular coat is reached. It is when the hyperplasia and the subsequent adaptive changes reach the nearest strata of plain muscular fibres that the vaso-formative process assumes a new character. The approach to a different kind of matrix tissue does not probably explain of itself the extraordinary demarcation of the discoid placenta from the

villous semicircle; in my former paper (pp. 574 and 586), I pointed out that the remarkable invagination of the blastodermic membrane appeared to have the effect of defining the discoid form of the first placental growth.[1] But it is the invasion of the muscular coat and the associated differences of vessel-formation that I am now solely concerned with.

The explanation of the peculiar secondary placenta of the guinea-pig is, from one point of view, to be sought for in the fact that the deeper tissues of the uterine wall, from whose hyperplasia it is derived, differ in important respects from the tissues nearer to the epithelial surface. It will be necessary, for the sake of clearness, briefly to recapitulate some of my former observations.

In the cross section of a horn of the guinea-pig's uterus, in its relaxed or non-hyperplastic condition, there is found, between the layer of epithelium on the inner surface, and the circular muscular coat, a considerable stratum of round or spindle-shaped cells; this region is named by Turner the subepithelial layer, and by Reichert the substratum. The necks of the utricular glands run through it in regular and radial order, their coiled extremities being in its deeper parts, and it is crossed also in very regular order by radial blood-vessels, of capillary structure. There is no very marked line of separation between this subepithelial tissue and the innermost of the muscular fibres; the inner, or circular muscular coat, appears to be an integral part of the substratum, and I quoted, from the memoir of Reichert, observations to show that it is both structurally and functionally independent of the outer longitudinal coat. The latter is a very distinct layer of cord-like longitudinal bands; it is separated by a well-marked interval from the circular muscular fibres, and in that interval the uterine blood-vessels

[1] My attention has been called to an oversight in my former paper, in connexion with the observations of Professor Schäfer, which I had quoted. In his paper, "A Contribution to the History of Development of the Guinea-Pig," in this *Journal*, vol. xi. 1876, he spoke of the hypoblastic membrane as not being invaginated. In printing the paper along with others issuing from the physiological laboratory of University College, London, he appended a note (January 1877), in which he asserted the invagination of the membrane behind the placental outgrowths. I had not seen that correction when I wrote, and I take this opportunity of pointing out the substantial agreement between Professor Schäfer and myself on that not unimportant point.

ramify. The arteries running through the abundant loose connective tissue that occupies the interval, give off numerous small branches which pierce the circular coat at right angles to the direction of its fibres, and as they traverse the cellular substratum in radial order and approach the epithelial surface, they assume the structure of capillaries. In the examination of such preparations, it does not escape notice that the small vessels cross the circular muscular coat at right angles to the direction of the muscle cells, while in the subepithelial region the cells lie around the vessels in any order. So far the relaxed or non-hyperplastic state of the uterine wall.

When the decidual hyperplasia begins, the round or spindle cells of the sub-epithelial tissue swell up, becoming large, spherical, or cubical elements with a central nucleus and a large zone of clear protoplasm. They are found at the same time to have attached themselves more definitely to the walls of the parallel and radial capillaries, and the whole sub-epithelial tissue becomes in the most obvious manner a perivascular tissue (see fig. 4 of the former paper). This tissue is, in the nature of things, as highly vascularised as any tissue can be. In the subsequent course of the placental formation, the perivascular cells aggregate themselves in rows to become the vaso-formative tracts of a new system of vessels, superseding the original capillaries; they form the walls of the new vessels, and, as the walls of the new vessels, they retain their whole thickness of protoplasm. It is not necessary to repeat here the description that I have given of these thick-walled vessels or of the spongy protoplasmic substance which represents their terminal expansions and which constitutes the bulk of the discoid placenta. The above resumé will enable me to contrast the process of new formation in the deeper layers.

The same hyperplasia that showed itself first in the layers immediately beneath the epithelium, extends after a time through the whole thickness of the subepithelial stratum and at length reached the cells of the circular muscular coat. As early as the fifteenth day the muscle cells are found to be greatly enlarged, and the somewhat slender staff-shaped nucleus has swollen to an enormous bulk, assuming at the same time an oval or spherical shape. The degree of hyperplasia is no less in the deeper

strata than in the superficial; and, up to a certain point, there is a close resemblance between the swollen individual cells in the two regions. The line of demarcation between the subepithelial stratum and the muscular stratum continues in the hyperplastic state much the same as in the resting or relaxed condition. In both conditions, the demarcation is not so much in the change from one shape or character of cell to another, but by reason of the greater compactness of the muscle-cells, of the general circular disposition of the stratum, and of the transverse direction of the blood-vessels through it. The subepithelial tissue readily assumes the character of a rich perivascular tissue, which again no less readily becomes the vaso-formative tissue of the placenta. Being a perivascular tissue, it is vascularised to the highest possible degree. On the other hand, the muscle-cells stand in a very different relation to the blood-vessels. The radial vessels, while traversing them, may be called transmitting vessels on their way to the region of their distribution or their capillary territory, viz., the subepithelial stratum. The muscular layer is clearly separated from the subepithelial layer, if not by the character of its cells, yet by the nature of its blood supply; and the wide divergence in external form between the placental formations in the two regions, depends in a great measure upon the different conditions of the matrix tissue as regards vascularity. The explanation of the peculiar destiny of the hyperplastic cells in the deeper strata lies in this, that it is *a hyperplasia taking place in a region inadequately supplied with blood.* The blood supply is disproportionate to the growth of tissue. The most singular effect of that disproportion is the abundant production of the large multinuclear blocks or masses of tissue, known as giant-cells. I have now reached the point where the illustrations come in.

Fig. 1 represents a group of cells of the circular muscular coat, showing all gradations from somewhat elongated elements with a single nucleus to large cubicular spherical masses with many nuclei. These cells are drawn exactly as they lie in the preparation, and they may serve, without further explanation, to show the origin of the giant-cells of that region from the hyperplasia of the ordinary cells of the tissue. Fig. 2 represents a much more complex condition of the deeper placental area, including the circular muscular coat. Beginning at the lower side

there is seen a portion of the circular muscular coat, no longer distinguishable as such owing to the great enlargement of its cells. The hyperplasia of the cells is frequently observed (in other preparations) to be greatest round about a blood-vessel; in such groups of muscle-cells, the nuclei may reach an enormous size without dividing. Beyond the crescentic belt of hyperplastic muscle-cells in the figure, multinuclear masses begin to appear. They are of all sizes and shapes. Very commonly their nuclei (which are small beside those of the cells with a single nucleus) are arranged in close order along one side of the cell, or round a part of its periphery, or, it may be, round the entire periphery; but they sometimes occur scattered irregularly throughout the substance of the cell. On the right hand side, the multinuclear masses are elongated, having a radial direction towards the upper surface. In the same part of the figure, they seem also to grow out from the deeper layer. Towards the left side of the figure, there are two larger multinuclear masses, one of which is excavated and has a dense cluster of nuclei exactly opposite the excavation. To the right of it, there is a blood-space, filled with red corpuscles, and having its boundaries indicated here and there by deeply-stained elongated nuclei.

What, then, is the special significance of such multinuclear masses in that region? The answer to this will be partly found in tracing their further development. It must be admitted at the outset that they have not all the same destiny. There is sufficient evidence that some of them become excavated, so as to form a portion of blood-sinus, their marginal nuclei forming the wall of the sinus. Two cells showing that transformation are represented in fig. 3; in *b*, it is conceivable that the peculiarly tinted and coarsely granular protoplasm would break up into a mass of red blood-discs. The most usual adaptation, however, of the giant-cells to become vaso-formative cells is somewhat different. The blood-channel is not usually formed in the centre of one cell, but it is an intercellular passage bounded by the close-set nuclei of two contiguous giant-cells. Many of the multinuclear masses have their nuclei only along one edge or side, and the nucleated sides of two such cells, coming into near apposition, form the nucleated walls of a blood-vessel. The unnucleated protoplasm of the cells then appears to decay. Following the

rows of red blood corpuscles from the deeper strata, they may be often observed to lie in the clefts between the cells; as the vaso-formative process advances, such intercellular clefts become blood-channels with definite nucleated walls. Two such blood-vessels, with deeply-stained nuclei, are drawn in the upper part of fig. 2. It will be observed, also, that the multinuclear mass below them has a dense cluster of nuclei on the side next to the vessel; that cluster or row of nuclei becomes in its turn the limiting or defining wall of another blood-channel, the new channel being the space between the marginal row and the independent blood-vessel already mentioned. Thus the lower side of the latter serves as a wall common to two blood spaces, and is, in fact, a mere partition in the midst of a common vascular tract.

Such vascular tracts, made up of a number of parallel blood-channels having their walls in common, are very characteristic of the deeper region of the guinea-pig's placenta, and especially of its secondary and cotyledonary portion. One of them is represented in fig. 4. When it is followed upwards towards the surface, it runs into villus-like processes such as those drawn in fig. 5 (under a somewhat lower power). These villus-like processes are taken from the semicircular row that constitutes the peculiar secondary or cotyledonary placenta. Their margins and their free extremities contain close-set nuclei, but their interior is a nearly uniform expanse of granular protoplasm. At the lower end, however, there occur linear rows of nuclei in its midst. These are the terminations of the parallel nucleated septa of the vascular tract already described; the rows of nuclei come to an end gradually in the granular protoplasm of the villus or cotyledon. Blood is also seen here and there inside the villus, not contained in definitely bounded places, but rather in the sponge-like protoplasmic substance. The fœtal vessels are applied to the nucleated surface of the villi or cotyledons, forming a series of vascular loops interdigitating with the latter. That arrangement is the same, according to Ercolani, as in the placenta of the ruminants. The villus-like or cotyledonary processes appear originally to have formed a system of anastomising trabeculæ passing from the deeper strata to the walls of the large blood-sinuses that enter the discoid body. The fœtal tufts of vessels

had penetrated into the intervals between the trabeculæ. By and by the latter had become broken off from the walls of the sinuses passing to the discoid placenta, and had thus acquired their free rounded extremities as described; while the sinuses from which they were detached retain a corresponding number of stunted nucleated prominences. I have discussed these and other points of adaptation in my former paper (p. 586), and I have only to add here a few words about the general features of the vaso-formative process in the deeper strata of the uterine wall.

The contrast between the vaso-formative process in the deeper layers and in the more superficial is easily stated. In the surface strata the large perivascular cells become fused into vaso-formative cords, each cell retaining its individuality up to a particular point. In the deeper layers the vaso-formative elements are multinuclear blocks or masses, and the walls of blood-vessels may be said rather to be carved out of a matrix-tissue of nucleated protoplasm. The linear pieces of tissue are those most serviceable for the new blood-vessels. The more cubical or spherical masses are found in the intervals between the linear vascular tracts, and they very frequently undergo necrosis. The hyperplasia in the deeper layers may be looked at from either of two points of view:—firstly, as a means towards a definite end, viz., the production of an additional placenta; or, secondly, as exemplifying the spontaneity or natural behaviour of the cells of the region under the sustained stimulus of a periodical sexual hyperplasia. Confining the attention solely to the latter aspect of the case, one observes, first of all, a tendency to the formation of multinuclear masses of tissue, and, in the next place, the decay or necrosis of the greater number of the multinuclear masses so formed. Those that survive do so by virtue of becoming the walls of blood-vessels; and those that decay incur that fate, because they are left on one side by the vascular tracts forming throughout the region. The formation of multinuclear masses, instead of a multitude of small independent cells, appears to depend on the circumstance that the vascular supply of the region is inadequate to the degree of the hyperplasia. The subsequent changes in the multinuclear masses exemplify one or other of two things; they show either the successful effort of the hyperplastic tissue to vascularise

itself, or they show its failure to do so. There is, in fact, a selection of some of the elements to form vascular tracts, and the decay of those not selected. The giant-cells, or the portions of them, that enter into the formation of a blood-sinus, do not decay. But for the giant-cell that does not participate in the vaso-formative process, there is no other alternative but to become caseous, or otherwise to break up into detritus from want of nourishment. Some of the giant-cells, as I have mentioned, contribute to form one side of a blood-channel, as in fig. 2; while others appear to become excavated so as to transmit the blood through their midst, as in fig. 3, *b* and *c*. At *a* of fig. 3, is shown another suggestive appearance of the giant-cell. It does not appear that that cell is part of a blood tract. It is hollowed out, and it contains an abundant brood of active nuclei all round the walls of its cavity. The same appearance is shown in a large excavated cell in fig. 2. The mere excavation of a giant-cell seems to conduce to its vitality and to the further proliferation of its nuclei. The position of the excavated mass in the line of the blood supply, or the adaptation of its cavity as a portion of a blood-channel, is the special concurrence of means to end, through which those masses play an intelligible part in the normal process of building up the placenta.

Explanation of Plate XVI.

Fig. 1. Group of cells of the inner muscular layer of the guinea-pig's uterus, showing the intra-cellular multiplication of nuclei (formation of giant-cells), during the placental hyperplasia. × 150.

Fig. 2. A portion of the deeper layer of the guinea-pig's uterus showing the placental hyperplasia in that region, and the associated vaso-formative process. Numerous giant-cells in various parts of the figure. The lowest, crescentic belt of denser tissue is the inner muscular layer. × 150.

Fig. 3. Three cells from the deeper layer of the guinea-pig's placenta. × 150. *a*, Very large giant-cell, excavated, and with its periphery crowded with nuclei. It lay in the midst of a blood-sinus; *b*, giant-cell with processes, excavated to form part of a blood-channel and branches; *c*, further stage of the vaso-formative process within a giant-cell. The cavity is occupied by red blood-corpuscles.

Fig. 4. A typical vascular tract in the deeper part of the guinea-pig's placenta. The blood-channel is, as it were, extensively subdivided by a number of parallel lines of nucleated protoplasm. × 150.

Fig. 5. Terminal villi or cotyledons of the secondary placenta in the guinea-pig. The vascular tract of the last figure runs up to the villous processes, and the linear nucleated protoplasm of the former shades off into the fainter rows of nuclei embedded in the substance of the latter. The surface of the villi is covered, in the preparation, with the fœtal chorionic tissue and vessels. × 90.

Fig. 6. Groups of cells from a granulating stump of the leg. × 300. *a*, Four cells, vacuolated, and with many nuclei on the periphery of the cells; *b*, two larger cells showing the same peripheral accumulation of nuclei; *c*, one such large cell, scattering or setting free its nuclei to mingle with the ordinary granulation cells round about.

Fig. 7. Giant-cells, illustrating their vaso-formative character. × 300. *a*, a vaso-formative giant-cell from the peripheral zone of a large brain tubercle, which was caseous in the centre; *b*, vaso-formative giant cell from tubercle of the spleen, in a case of general tuberculosis in an adult; *c*, vaso-formative giant-cell found in unhealthy granulation-tissue.

ON THE PHYSIOLOGICAL TYPE OF THE GIANT-CELLS OF TUBERCLES AND GRANULATIONS. By C. CREIGHTON, M.D., *Demonstrator of Anatomy, Cambridge University.* (Plate XVI).

IN the foregoing paper I have described the occurrence of giant-cells in the placental area of the guinea-pig's uterus, and I have endeavoured to arrive at the circumstances under which they occur. They are derived from the ordinary cells of the deeper strata (muscular) of the uterine wall, apparently by the intra-cellular subdivision of the original single nucleus. The particular form of periodical uterine hyperplasia, which leads to the formation of giant-cells, occurs in the denser and less vascular region of the circular muscular coat; the sub-epithelial tissue, which contributes most to the building up of the placenta, is looser in texture and much more perfectly vascularised, and it is not the seat of giant-cell formation. Its cells, after remaining for a time as perivascular cells, become vaso-formative cells, and that is also the destiny of the giant-cells in the deeper region. In both situations the hyperplasia of the tissue is followed by the production of new vessels. It may be said that the pre-existing vessels are inadequate to the nourishment of the greatly over-grown tissue. However that may be expressed, there is soon observed a process of formation of new and larger vessels throughout the entire region of hyperplasia. The cells that go to form the new vessels are the hyperplastic elements themselves, and the peculiarity of the placental new formation is, that it consists simply and solely of thick-walled vessels, and of the spongy or cavernous protoplasmic tissue which represents their capillary territory. The hyperplastic cells become vaso-formative cells; and those of them that do not share in the vaso-formative process undergo either a change into mucus-like fluid, or into granular or caseous detritus. The decay of the cells in the intervals between the newly formed vascular tracts is obvious both in the superficial layers and in the deeper. It takes place most extensively in the latter, which is the region of giant-cells, and these multi-

nuclear elements are constantly found in various stages of necrosis or breaking-up.

The giant-cells of the placenta resemble in form and general characters the giant-cells of tubercles and other morbid products, and they appear to me to furnish an almost perfect physiological type or analogy for the pathological giant-cells. The latter have been considered by certain writers, whom I shall proceed immediately to quote, to be vaso-formative cells, on the evidence derived from the pathological conditions themselves. Whatever physiological analogy has been sought for them, has always been in the vaso-formative processes of the embryo, and no complete correspondence has been found therein. But the vaso-formative processes in the uterine wall, which result in the building up of the placenta, are recurring periodical processes in the adult, having the mature tissues for their basis. It is not surprising, therefore, to find that the correspondence with the pathological vaso-formative phenomena is very much greater. Further, the differences between the new formation of vessels, in the superficial and in the deeper strata of the guinea-pig's uterus, correspond to certain differences between one kind of pathological product and another. Both in the normal and in the pathological cases, giant-cells appear to be the index of hyperplasia associated with feeble or imperfect vascularity.

I do not propose to refer to all the numerous writings on giant-cells, from the papers of Schüppel and Langhans down to the present date. A great part of that literature is occupied with the question of their tissue-origin, a question which is easily settled for the giant-cells of the placenta, and which may, for the present purpose, be left untouched for those of tubercles and granulations. There are two writers who have more particularly discussed the significance of giant-cells in pathological processes, and whose conclusions correspond with those suggested by the analogy of the placental giant-cells. The first of these is Professor Brodowski, whose comprehensive treatment of the question is of permanent interest and value. The second is Dr Ziegler, who has embodied in his two elaborate memoirs the results of experiments, and of the usual kind of pathological observations, and whose conclusions have become more widely

known, especially through the prominence given to them in the recent work of Professor Cohnheim on *General Pathology.* It will be necessary to refer to the observations of those two writers, and I shall include a brief notice of the corroborative observations on the *myéloplaxes* of tumours, by MM. Malassez and Monod, in the number of the *Archives de Physiologie, normale et pathologique,* received while this paper was in preparation.

Observations of Brodowski (Virchow's Archiv, vol. 63, 1875.)—The author refers to several earlier writers who had considered pathological giant-cells to be intravascular formations, taking origin either in the tube of a lymphatic or of a blood-vessel, and more particularly from the proliferation of the endothelium. Wegner, in treating of pathological bone-resorption, had pointed out a different relation of giant-cells to blood-vessels; he considered them to be hypertrophic outgrowths of the vessel-walls, and not impossibly destined themselves to form blood-vessels.

So far confirming those somewhat conflicting suggestions of an association of giant-cells with the vessels, Brodowski concludes from his own observations that giant-cells take origin, not within the lumen of vessels, nor from the walls of old vessels or of new-formed vessels whose formation was already complete, but from the elements out of which new vessels would be formed. He, therefore, considers giant-cells always to have an *angioblastic* (vaso-formative) significance.

Employing chiefly tubercles in the spleen and in the medulla of bone, he found evidences that the smaller variety of giant-cells (showing all transitions to the larger) played a distinctly vaso-formative part. The multinuclear element was connected with the wall of a capillary by one or more bridges of protoplasm, illustrating the same kind of vascular extension as had been already described (by Rouget and others) for normal growing vessels. Sometimes the part of the protoplasmic bridge next the wall of the capillary was hollow, one or more vacuoles having formed in it, in the manner described by Rouget for the normal *cordons angioplastigus.* By the process of excavation, otherwise spoken of as a colloid degeneration of the protoplasm, the lumen of the new vessel was formed.

In like manner, cases of the larger giant-cells were seen, forming a direct extension of vessels themselves new formed but already finished. The formation of giant-cells could thus be traced to an abnormal productive activity of the blood-vessels. The abnormality might be stated under two heads: (1.) Hypertrophy of certain parts of the protoplasmic rudiments of new vessels, with increase of the number of nuclei, and leading to variously shaped giant-cells; and (2) retardation or stoppage in the further development of these misshapen rudiments. In spite of the retardation or pause in the vaso-formative process, the giant-cells still showed, if only in a partial way, this or the other appearance suggestive of a further development into blood-vessels. To that class of appearances belong the already mentioned vacuoles,

the formation over a greater or less extent of a cavity analogous to the lumen of a vessel, and the more or less complete division of the protoplasm corresponding to that which precedes the formation of the endothelial cells in capillaries. The most striking vaso-formative appearances of giant-cells that are figured in the plates were found in syphilitic gummata of the heart-substance; a very high magnifying power is used to bring out the effect.

Brodowski does not assert that the formative tissue of new blood-vessels is the only source of giant-cells. To prevent misunderstanding he would apply to the particular class of giant-cells the name of *angioblasts*, qualifying the name according to the size, form, number of nuclei, &c., with such adjectives as small, large, gigantic, spherical, pear-shaped cylindrical, misshapen, reticular, without nuclei, with many nuclei, &c.

The author then passes to consider the relation of this new doctrine of giant-cells to the question of tubercle. Tubercle, after passing through vicissitudes of definition, was at length thought to be specifically characterised by the invariable presence of giant-cells. However, the same giant-cells have been found by Brodowski himself and by other writers (whose observations are summarised and augmented by Friedländer in a paper in Volkmann's *Sammlung*), in a variety of situations, and in the midst of the most diverse pathological processes. Among the pathological conditions giving origin at least to occasional giant-cells are:—Elephantiasis Arabum, lupus, syphilitic visceral degenerations, granulations of chronic ulcer, the indurations of glanders in the nasal mucous membrane of man, the floor of a small shallow ulcer of the cervix uteri, an ulcerating tumour on the lobe of the ear, the walls of a freshly extirpated ulcus rodens of the cheek, the walls of a cystic mammary tumour, the substance of a cancer that had grown in the cicatrix remaining from the extirpation of a rodent ulcer.

The presence of giant-cells, not different from those of miliary tubercle, in all of these conditions, inclined Friedländer to view them as evidences of "local tuberculosis," and as proof of the affinity of the respective processes with the tubercular process. The catalogue of morbid products that contained giant-cells was subsequently increased by Köster, the following being added:—caries fungosa, scrofulous osteitis and osteomyelitis, benign granuloma of the conjunctiva, syphilitic ulcerations, abscess of breast, granuloma of the iris, ulcer of the tongue. These also, Köster included as local tubercles, and he differed from Friedländer chiefly in the opinion that such local formations of tubercles did not take place in previously healthy tissues, but in the midst of new-formed connective tissue, and more especially in granulation tissue.

After presenting these conclusions of Friedländer and Köster, Brodowski proceeds to remark on the confusion introduced into pathology by asserting a tuberculous character for such morbid conditions as syphilitic ulcers and gummata, or the indurations of glanders. "The sole means," he observes, "of escaping from such confusion is to assign to the new formation, called into existence as it is by so

diverse pathological excitants, another name representing not the form of the morbid product, but its histological structure. Such a name readily suggests itself . . . . . . It is well known that ordinary granulation tissue consists of cells like white blood-cells, of a small quantity of delicate ground-substance, and in general of a considerable number of new-formed blood-vessels. *The whole difference between ordinary granulations and the formations recently designated as tubercles, consists in this, that the place of the mature blood-vessels is in the latter taken by the more or less malformed or mishapen rudiments of vessels, that is to say by angioblasts, either purely of the giant kind, or of the giant kind and the reticular combined, or of the reticular variety alone.*" In favour of this view is the observation of Köster, that it is precisely in granulation-like tissue that the so-called local tubercles are found. The name that Brodowski adopts is accordingly, *granuloma giganto-angioblasticum.* The giant-cells are therefore no indication of a specific new formation, but they are found now and then to characterise granulation tissue in the lungs and elsewhere, and they mean neither more nor less than the failure of the vaso-formative cells to reach that ultimate development by virtue of which granulations, under ordinary circumstances, become so highly vascularised.

These well-reasoned conclusions of Professor Brodowski, emanating from Warsaw, a somewhat remote scientific centre, cannot be said to have attained the place that is due to them in the pathological literature of this country, nor indeed in that of other countries. The observations of Dr Ziegler, published in the course of the following year, have proved more attractive, owing no doubt to their more elaborate character, although they do not appear to modify in any material points the conclusions of the earlier writer, nor to carry these conclusions much farther.

Observations of Ziegler (1. Experimentelle untersuchungen über die Herkunftder Tuberkel-elemente, mit besonderer Berücksichtigung der Histogenese der Riesenzellen. 4to, with five plates, Würzburg, 1875. 2. Untersuchungen über Pathologische Bindegewebs-und Gefässneubildung, 4to, with seven plates, Würzburg, 1876). The summary of literature given by Ziegler in both his monographs is very complete, and is well worthy of perusal. The earlier portion of the first monograph is occupied with an account of experiments and observations to determine the histogenetic origin of giant-cells. It is not the endothelium, nor the fixed connective tissue-cells, nor protoplasmic masses in the sense of Schüppel, nor coagulated fibrim, out of which giant-cells and the surrounding epithelioid cells are formed; but it is to the colourless blood-corpuscles, the wandering-cells, that these formations owe their origin. The evidence for the statement follows. It was chiefly obtained through the well-known ingenious experiments of introducing beneath the skin a pair of small plates of thin glass,

cemented together at the four corners so as to leave a narrow interval between their opposed surfaces. The most convenient size of the plates was found to be rather less than ½ inch broad, and rather more than ½ inch long. The most successful experiments were in dogs; the small capillary chamber was deposited in a subcutaneous cavity, made by a single cut through the skin and by working the handle of the scalpel to and fro in the loose subcutaneous tissue; the situations chosen were the inner side of the thigh, various parts of the abdominal wall, and the scapular region. The glass chamber was retained in the cavity by stitching the edges of the wound. In most cases the wound healed by the first intention, and the chamber was allowed to remain from ten to twenty-five up to seventy days. A table of the experiments follows, and a detailed description of typical appearances found between the glass plates, after various periods of retention in the subcutaneous cavity. Colourless corpuscles had wandered into the capillary space between the plates, and, in a certain small proportion of cases, they escaped retrograde or necrotic changes, and underwent a further formative development, producing a vascularised tissue with giant-cells and epithelioid cells. The chamber was encapsuled in granulation tissue of the subcutaneous space, and the granulation-capsule often showed a pus-forming surface next to the glass plates. It is not necessary for the present purpose to follow the whole of Ziegler's observations. I select one case from his first monograph, in which the giant-cells and the new formation of blood-vessels between the glass plates appeared to have a close relation with one another (p. 51). The capillary chamber had remained in the subcutaneous space (in a dog) for 38 days. A great part of the preparation (the new-formed tissue between the plates) is penetrated with loops of blood-vessels. Carefully following the loops, one comes upon elongated giant-cells at various points. They represent the swollen end of a vessel. The transition from the blood-containing vessel to the giant-cell is effected by a "vessel" without lumen, made up of granular cells, and marked off from the surrounding tissue by a membranous thickening on its surface. It is in the second monograph of Ziegler that the relation of giant-cells to the new formation of vessels is more especially discussed, the observations being derived from the original glass-plate preparations, as well as from the granulation tissue that encapsuled them, and from the ordinary pathological fungous granulations.

I must content myself with referring to Ziegler's second and highly instructive monograph in the most general way. The exclusively vaso-formative significance which was assigned to giant-cells in his first publication (and only as an observation by the way), appears in a modified form in the second. They are taken to be a formative material both for vessels and for connective tissue, the more for the former in so far as vessels must be formed before the development of connective tissue can proceed. The vessels are chiefly formed in the intracellular manner by budding; but it appears that such vessels sometimes form without connexion with the blood-stream, and as passages between linear aggregate of cells.

Giant cells occur more or less in all granulation tissues. They are

most numerous and distinct in the tuberculous inflammations. The author's statements are limited to the local or primary tubercles, so as not to complicate the subject with the question of secondary or infective tuberculosis. Tuberculous granulations owe their distinctive structural features to defective vascularisation of their tissue. Cohnheim (*Vorlesungen über allgemeine Pathologie*, 1877, p. 613) thus summarises the observations of Ziegler. There is one circumstance common to all the cases of local tuberculosis, and that is the insufficient vascularisation of the new-formed tissue (product of inflammation, according to Ziegler). It is because the new formation of vessels does not proceed with adequate vigour, that there is none of the ordinary cicatricial tissue-formation; the granulations assume a spongy character, and all the pus-cells, epithelioid cells, and giant-cells, which would otherwise have been applied to the formation of connective tissue, now combine, as Ziegler says, to form the non-vascular and therefore short-lived tubercle nodule. "Have we not here," asks Cohnheim, "the most classical proof that tubercle may develop by reason of a defective organisation of blood vessels (*auf Grund einer fehlerhaften Gefässeinrichtung*)?"

Observations of Malassez and Monod (*Archives de Physiologie normale et pathologique*, July and Aug., 1878). This paper deals with the *myéloplaxes* of tumours, but the historical survey, occupying the latter half of the paper, refers more or less briefly to the whole voluminous literature of giant-cells, and covers the same ground as the surveys of Brodowski and Ziegler. The observations of the French authors themselves were made chiefly on three cases. One of them was a case of tumour primary in the testicle, and secondary in the retroperitoneal lymphatic glands, liver, spleen, kidneys, and lungs, the secondary growths alone being available for the investigation; another was a vascular epulis, and the third was a fibrous epulis. The giant-cells that were found in these cases appeared to have a vaso-formative significance. The *myéloplaxes* anastomosed with one another and presented growing points, and they were occupied with a coarsely granular protoplasm, ovoid nuclei with large nucleoli, vacuoles, and even cavities filled with blood-globules. In one word, these elements represented the vaso-formative cells and tracts of the normal vascular development, as described by Rouget and Ranvier. Between the giant-cells of obviously vascular parentage, and the more common and usually described forms, there existed a series of intermediate forms possessing the same significance as the former. These vaso-formative *myéloplaxes* are not perfect elements, special to certain tissues, but they are metatypical vascular formations. Tumours with giant cells should not form a group apart; they are simply a variety of sarcoma distinguished by certain *angioplastic* features. It is unnecessary to point out how minutely these observations on tumours confirm the earlier statements of Brodowski for the more inflammatory new formations which he groups under the name of *granuloma giganto-angioblasticum*.

I have given in fig. 7 three cells showing the vaso-formative agency of pathological giant-cells. The cell *a* is from the peripheral zone of a large caseous tubercle (so-called solitary tubercle) of the

choroid plexus, in a case of caseous osteo-myelitis of vertebræ, with caseous or tuberculous testicle, numerous large tubercles of the pia mater, and especially of the interior of the cerebellum, and smaller miliary tubercles of other places. The brain tubercles were opaque and caseous in the centre, but with a narrow peripheral zone of growing or non-caseous tissue. In the peripheral zone were numerous blood-channels, and it was not difficult to find here and there elongated multinuclear masses, such as in the figure, that were obviously on the way to become portions of the vascular channels. The cell *b*, from a tubercle of the spleen in a case of acute miliary tuberculosis in an adult, shows equally well the marginal arrangement of the nuclei; the giant-cells in the particular spleen-tubercles had a greater resemblance to the sections of blood-vessels than any that I have seen, owing to the very regular and close order of their nuclei round the margin, and owing also to the very granular and yellowish appearance of the cell contents, suggesting a mass of somewhat broken-down red blood-corpuscles. The cells *b* and *c* of fig. 3 are illustrative cases from the placenta, where the vaso-formative agency of the giant-cells was put beyond doubt by the large amount of collateral evidence.

The cell *c* in fig. 7 is a single instance of elements that are found abundantly in unhealthy granulations; they are well figured in plate 2 of Ziegler's second monograph, representing the appearances found between the glass plates after forty-eight days' retention in a subcutaneous cavity. The cell *c* is marked by a peculiar appearance as if of a central tube with highly refracting vitreous outlines. The appearance is very common throughout the case from which *c* is taken (a granulating stump of the leg after Syme's amputation at the ankle, which failed to cicatrise, and had to be amputated below the knee); and the peculiar central lumen is sometimes seen to extend through a row of giant-cells, as if they were strung upon a thin spicule of glass. Whether this is a "vitreous" transformation of the central line of the cells, representing the more usual "colloid" transformation, I am unable to say. The width of the vitreous band or lumen is so uniform throughout, and its outlines so hard, that one is apt to think that the appearance may be possibly due to inorganic shreds or particles accidentally introduced.

The explanation of fig. 6 will complete what I have to say in the way of description, and will lead up to some concluding remarks of a general nature. The cells drawn in fig. 6 are found in the midst of ordinary granulation tissue in the granulating stump above referred to. At *a* is a group of four cells, all of them excavated in the centre, and bearing a larger or smaller brood of nuclei at one side of their periphery; the smallest of them is not much larger than some of the ordinary granulation cells among which it lies, and a series of transition sizes could easily have been given. At *b*, a further extension of the same intra-cellular formation of nuclei is shown in two cells; these elements are very striking as they lie here and there among the ordinary granulation cells, forming a number of deeply-stained spots in the field of vision. At *c*, the nuclei, hitherto contained within the limits of an individual cell, have scattered, and each nucleus will henceforth be a granulation-cell on its own account. The physiological type of these singular appearances is given at *a*, fig. 3, representing an enormous cell of the placenta, excavated in the centre, and, as it were, incrusted with a dense collection of deeply-stained nuclei.

The cells drawn in fig. 6 are giant-cells that have met with conditions most favourable to their vitality, and to the ultimate survival and independent existence of their nuclei. It appears to be the excavation of the cell that has enabled its nuclei to proliferate to an unusual degree, and the cell as a whole to escape the common fate of giant-cells, viz., caseation or necrosis. The many nuclei, instead of being scattered throughout the substance of the cell, are collected at its periphery, and are in contact internally with an accumulation of fluid. The excavation of multinuclear masses may be observed in like manner in the placenta, and there also the periphery of the central space carries a dense and deeply-stained cluster of nuclei, as in the very large mass towards the left upper side of fig. 2. In the placenta it is not unreasonable to suppose that sometimes the excavation ultimately communicates with and forms a part of a blood sinus; but the cells in fig. 6, from granulation tissue, do not appear to take part in the formation of the blood-vessels of the tissue. The excavation or vacuolation is in them an end in itself, and it ensures the vitality of the intra-cellular brood. In like manner, the

Fig. 4. A typical vascular tract in the deeper part of the guinea-pig's placenta. The blood-channel is, as it were, extensively subdivided by a number of parallel lines of nucleated protoplasm. × 150.

Fig. 5. Terminal villi or cotyledons of the secondary placenta in the guinea-pig. The vascular tract of the last figure runs up to the villous processes, and the linear nucleated protoplasm of the former shades off into the fainter rows of nuclei embedded in the substance of the latter. The surface of the villi is covered, in the preparation, with the fœtal chorionic tissue and vessels. × 90.

Fig. 6. Groups of cells from a granulating stump of the leg. × 300. *a*, Four cells, vacuolated, and with many nuclei on the periphery of the cells; *b*, two larger cells showing the same peripheral accumulation of nuclei; *c*, one such large cell, scattering or setting free its nuclei to mingle with the ordinary granulation cells round about.

Fig. 7. Giant-cells, illustrating their vaso-formative character. × 300. *a*, a vaso-formative giant-cell from the peripheral zone of a large brain tubercle, which was caseous in the centre; *b*, vaso-formative giant cell from tubercle of the spleen, in a case of general tuberculosis in an adult; *c*, vaso-formative giant-cell found in unhealthy granulation-tissue.

ON THE PHYSIOLOGICAL TYPE OF THE GIANT-CELLS OF TUBERCLES AND GRANULATIONS. By C. CREIGHTON, M.D., *Demonstrator of Anatomy, Cambridge University*. (Plate XVI).

IN the foregoing paper I have described the occurrence of giant-cells in the placental area of the guinea-pig's uterus, and I have endeavoured to arrive at the circumstances under which they occur. They are derived from the ordinary cells of the deeper strata (muscular) of the uterine wall, apparently by the intra-cellular subdivision of the original single nucleus. The particular form of periodical uterine hyperplasia, which leads to the formation of giant-cells, occurs in the denser and less vascular region of the circular muscular coat; the sub-epithelial tissue, which contributes most to the building up of the placenta, is looser in texture and much more perfectly vascularised, and it is not the seat of giant-cell formation. Its cells, after remaining for a time as perivascular cells, become vaso-formative cells, and that is also the destiny of the giant-cells in the deeper region. In both situations the hyperplasia of the tissue is followed by the production of new vessels. It may be said that the pre-existing vessels are inadequate to the nourishment of the greatly over-grown tissue. However that may be expressed, there is soon observed a process of formation of new and larger vessels throughout the entire region of hyperplasia. The cells that go to form the new vessels are the hyperplastic elements themselves, and the peculiarity of the placental new formation is, that it consists simply and solely of thick-walled vessels, and of the spongy or cavernous protoplasmic tissue which represents their capillary territory. The hyperplastic cells become vaso-formative cells; and those of them that do not share in the vaso-formative process undergo either a change into mucus-like fluid, or into granular or caseous detritus. The decay of the cells in the intervals between the newly formed vascular tracts is obvious both in the superficial layers and in the deeper. It takes place most extensively in the latter, which is the region of giant-cells, and these multi-

Fig. 4. A typical vascular tract in the deeper part of the guinea-pig's placenta. The blood-channel is, as it were, extensively subdivided by a number of parallel lines of nucleated protoplasm. × 150.

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ON THE COTYLEDONARY AND DIFFUSED LACENTA OF THE MEXICAN DEER—(*Cervus Mexicanus*). By PROFESSOR TURNER, M.B., F.R.S.

IN the month of November, my friend Professor A. H. Garrod kindly forwarded to me the gravid uterus of a *Cervus Mexicanus* which had died in the gardens of the Zoological Society, London. The uterus was in the earlier stage of pregnancy, and contained twin fœtuses, one in each horn. Each fœtus measured 3½ inches from the vertex to the root of the tail.

The uterine cornua possessed the well-known form one is familiar with in the Ruminantia, and owing to the presence of twin fœtuses the horns were of equal size. About one inch from the Fallopian tube, each cornu curved suddenly backwards, and a fold of mucous membrane projected into the cavity at the spot where this bend took place. A well marked septum which separated the cavities of the two horns was situated in the corpus uteri, and terminated close to the os uteri in a free crescentic border.

The chorion formed a continuous membrane, extending from the tip of one cornu to that of the other, and measured 21 inches in length. Its uterine surface presented a very remarkable appearance owing to the presence, not only of large and small cotyledons, but of a diffused distribution of villi over various parts of the surface.

Each horn of the chorion possessed three elongated caruncules (cotyledons), the largest of which was 5 inches, the shortest 3½ inches, whilst the greatest breadth was about ¾ of an inch. Each of these caruncules was indented by transverse or oblique furrows which gave the appearance of a division into smaller segments. But each horn possessed in addition several dozen tuft-like patches of villi, which formed small caruncules varying in diameter from $\frac{1}{10}$th to $\frac{5}{10}$ths of an inch. These caruncules were often in close proximity to each other, at other times separated by narrow intervals. They were not distributed generally over the chorion, but were found more especially in proximity to the larger caruncules, and were quite absent from the chorion in the

neighbourhood of the os uteri, and over a considerable area at the free end of each horn.

In the intervals between the large and small caruncules, on the surface of a portion of the chorion in the neighbourhood of the os, and over a large part of the surface at the free ends of the horns, villi were diffused in extensive patches, irregular both in form and size. These patches were just visible to the naked eye and required the use of a pocket lens to follow out their distribution. They did not, however, cover the entire surface of the membrane in the regions where the caruncules were absent, as smooth areas, perfectly free from villi, were present in the regions of the os and Fallopian tubes and some other parts of the chorion. Owing to a constriction in the chorion opposite the fold of the mucous membrane, which projected into the uterine cavity near its free end, it at first sight appeared as if the terminal part of the bag of membrane was a diverticulum allantoidis, but on more careful inspection it was seen that the surface of this part of the membrane was for the most part covered with a diffused patch of villi, which proved it to be the chorion proper. Hence, the arrangement of the membranes in *Cervus Mexicanus* supports the opinion which I expressed in my account of the placenta of the hog-deer,[1] that the placenta of the Cervidæ may be distinguished from that of the hollow-horned ruminants by the absence of the diverticula allantoidis.

The villi composing the large caruncules were elongated and arborescent. Each possessed a main stem from which branches arose that again divided into smaller off-shoots, which were filamentous and cylindriform. These villi had a general resemblance to those of the rain-deer,[2] but the practised eye could distinguish the villi of one animal from those of the other; for in the *Rangifer tarandus* the branches arising from the main stem of the villus were more numerous, more slender, and more closely clustered together than in the *Cervus Mexicanus*.

In the smaller caruncules of the Mexican deer the villi were not only much shorter than in the larger caruncules, but had broader bases of attachment to the chorion. Their branches also were very short and had more of a leaf-like than a filamentous form.

[1] This *Journal*, October 1878.

[2] Described by me in this *Journal*, July 1878.

In the diffused villous patches the villi were arranged, not in tufts as in the mare, cetacean and *Hyomoschus*, but as shallow ridges, having a general resemblance to those which I have described in the pig.[1] These ridges, though often running parallel to each other for some distance, usually at length converged and became continuous with each other, and sometimes indeed formed a reticulated arrangement.

The sac of the allantois extended from the free end of the horn of each chorion to the region in relation to the os uteri, where it terminated, and the walls of the two allantoic sacs came in contact with each other in this locality; the sacs themselves, however, were quite distinct, as fluid injected into one sac did not pass into the other.

The sac of the amnion in relation to each fœtus was comparatively small, and restricted to about the middle of each horn of the chorion. The amniotic investment of the umbilical cord, and the surface of the amnion over a great part of the wall of the sac were studded with minute semi-translucent corpuscles; so minute indeed were they as to be scarcely visible to the naked eye. On microscopic examination they were seen to consist of crowds of polygonal scaly cells, with distinct nuclei, and corresponded, therefore, in structure with the similarly situated but larger and more opaque corpuscles I have described in the raindeer and hog-deer. Sparingly scattered over the free surface of the allantois, and projecting into its sac, were opaque yellowish corpuscles, about twice the size of the corpuscles of the amnion. They were sometimes attached to the allantois by a slender pedicle of that membrane. They were much tougher than the amniotic corpuscles and their structure was more difficult to determine. When digested in glycerine and when magnified 300 diameters they had an ill-defined fibrous aspect, but, on the subsequent addition of acetic acid the fibrillated character disappeared, and a small proportion of ovoid, polygonal, and fusiform cells, like the corpuscles of embryonic connective tissue, came into view. They differed from the corresponding bodies in the hog-deer in projecting into the sac of the allantois, and in not having undergone calcareous degeneration, so that their resemblance to the hippomanes in the mare was more clearly marked.

[1] Lectures on Comparative Anatomy of Placenta, 1st series. Edinburgh, 1876.

The free surface of the uterine mucous membrane was adapted to the outer surface of the chorion. In each cornu were three elongated cotyledons corresponding in size and form to the fœtal caruncules. Each cotyledon projected for from $\frac{2}{10}$ths to $\frac{3}{10}$ths of an inch beyond the surface of the surrounding mucous membrane, and was indented by transverse and oblique furrows. The surface of each cotyledon was studded with the mouths of numerous pits in the cotyledon, in which the villi of the chorion had been lodged. Opening into each of these pits were secondary pits or crypts, in which the branches of the villi, with their terminal and lateral off-shoots, had been contained. As the uterine arteries had been injected with gelatine and carmine, the walls of the crypts and pits were seen to be very vascular. The epithelial lining of the pits and crypts was for the most part shed, but patches of cells were occasionally seen in position on their walls, and loose cells were floating about in the fluid in which the sections made through the cotyledon were mounted.

But in addition to these large cotyledons there were numerous patches of crypts for the lodgment of the short villi of the smaller caruncules of the chorion. These patches were not elevated into well-defined cotyledons, above the general plane of the surrounding mucous membrane, but, in conformity with the structure of the villi they had contained, they presented a crypt-like character, having a general resemblance to the crypts in the uterine mucosa of a gravid cetacean.

In correspondence with the regions where the patches of diffused villous ridges of the chorion had been situated, the free surface of the uterine mucosa presented narrow furrows in which the shallow villous ridges had been lodged. The walls of these furrows, as well as the walls of the crypts for the reception of the villi of the smaller caruncules, were very vascular, and were readily distinguished by their deeper red colour in the injected uterus from the smooth portions of the mucous membrane in apposition with the non-villous areas of the chorion. The crypts were lined by an epithelium, which had, however, been shed from the general surface of the mucosa, probably from the soaking in warm water to which the uterus had been subjected in the process of injection.

Elongated, branched, and tortuous tubular glands were readily

seen in the deeper layer of the mucosa. They extended in a large part of their length almost parallel to the free surface, but ultimately inclined to that surface to open by very obliquely directed mouths. Many of these orifices were seen on the smooth areas of the mucous membrane. The glands contained an epithelium, the cells of which had for the most part indistinct outlines, as if they were in process of disintegration, though occasionally cells having an elongated columnar form were seen.

In the presence of a small number of large cotyledons in each uterine cornu, the Mexican deer corresponds with the other Cervidæ that have been described. But it possesses, in addition, numbers of small cotyledons and patches of diffused villi, so that in these particulars it presents an exceptional arrangement to the Cervidæ generally, so far as their placentation has been studied.

Many years ago Professor Owen pointed out[1] that on the chorion of the giraffe not only were many large cotyledons, but in the inter-spaces between them numerous smaller cotyledons, varying in diameter from 2 inches to 2 lines, were situated. Subsequently I showed[2] that short club-shaped villi also arose, either singly or in rows and clusters, from the surface of the chorion of this animal, so that the giraffe in this particular approximated to the type of the diffused placenta.

The placenta of the Mexican deer, however, possessed a combination of the cotyledonary with the diffused type of placenta much more strikingly marked than was the case in the giraffe, the areas of diffused villi being proportionally more extensive, so that they, without doubt, played a more important part in the nutrition of the fœtus. The occurrence of this combination of the diffused and cotyledonary types in the same placenta strengthens the argument I have previously advanced[3] of the relation which subsists between these two forms, and of the possibility, on the theory of evolution, of the cotyledonary placenta being evolved out of a diffused form "through the

[1] *Trans. Zool. Soc.* vol. iii.

[2] *Lectures on Comparative Anatomy of Placenta*, p. 67. Edinburgh, 1876.

[3] Some general observations on the placenta, with special reference to the theory of evolution. This *Journal*, vol. xi. p. 33.

atrophy of villi and crypts on some portions of the chorionic and uterine surfaces and their increased development on others." Owing to the retention of a diffused distribution of the villi on the surface of so large an area of the chorion, it will be a matter of interest, for those who may have opportunities of dissecting *Cervus Mexicanus*, to observe, if in other features of its anatomy it approaches more closely than do the other Cervidæ, to the Perissodactyla, or to those Artiodactyles, as the Tragulidæ and Camelidæ, which retain the diffused type of placenta.

The existence in the genus *Cervus* of a species which is not purely cotyledonary in its placentation, whilst the other members of this genus, so far as we are acquainted with them, are purely cotyledonary, furnishes us with an additional argument to those which I have advanced in previous memoirs, that the placenta should not be accepted as a dominant organ in the Classification of the Mammalia.

ON EXOSTOSES WITHIN THE EXTERNAL AUDITORY MEATUS.—By Professor TURNER, M.B., F.R.S.

IN 1864 Professor Seligmann directed attention to the presence[1] of exostoses in the external auditory meatus of some specimens of American crania, which had undergone artificial elongation. He had seen these skulls in various collections, where they were described as "Titicaca's, Huanka's, and Aymara's," and of six such crania, five possessed exostoses in this locality.

In the first volume of the *Archiv für Ohrenheilkunde*,[2] Professor Welcker, of Halle, described the presence of exostoses in the external meatus in the crania of two natives of the Marquesas islands, which he had received from the collection of Dr J. Barnard Davis. In one specimen (No. 784), a man aged about 36, three small exostoses were situated in the left auditory meatus, one of which grew from the upper part of the anterior wall, and the

[1] Cited by Welcker as contained in the *Sitzungsberichte der Kais. Acad. in Wien*, 1864, p. 55, but I cannot find it in the Proceedings of the Academy for that year.

[2] Ueber Knöcherne Verengerung und Verschliessung des äusseren Gehörganges.

other two from the upper part of the posterior wall, whilst in the right meatus, indications of exostoses growing from the posterior wall were seen. In the other cranium (No. 593), that of a man aged about 50, a small pedunculated exostosis sprang from the upper part of the anterior wall of the right meatus, but the left meatus was quite sound.

In his *Thesaurus Craniorum* (London, 1867) and in its supplementary volume (London, 1875) Dr J. Barnard Davis refers to the presence of auditory exostoses in crania in his magnificent collection, not only in the above two skulls, but to another specimen from the Marquesas islands (No. 1132), to a skull from the Loyalty islands, three Kanaka crania from the Sandwich islands, the skull of one of the Khas tribe of Nepaul, the skull of an ancient Roman and four Peruvian crania belonging to the Quichua Indians.

Although I have been acquainted for several years with Professor Welcker's paper, during which time a large number of crania, both European and exotic, have passed through my hands, it was not until a few weeks ago that one possessing exostoses in the meatus came under my observation.

In November 1878 one of my pupils, Mr Robert Simpson, brought me an adult male skull, which had been obtained by one of his relatives in a saltpetre mine at or near Pisagua, Peru. The skull was an excellent specimen of an artificially deformed Peruvian skull, with the frontal bones sloping backwards in an almost straight line from the glabella, and with the occipital bone also having a very decided backward inclination. It closely resembled the distorted cranium of the Aymara, which was also from Pisagua, figured by Dr J. B. Davis in his *Thesaurus Craniorum*, p. 245.

On examining the external auditory meatuses I found that they were both almost entirely occluded by hard, ivory-like exostoses, growing from their walls. In the right meatus two of these exostoses were present. One, almost blocking up the orifice, arose from the anterior wall, by a constricted peduncle; it was pea-like in form, and possessed a diameter of nearly $\frac{3}{10}$ths of an inch; the other, more elongated in shape, had a broad base of attachment to the anterior wall, and was more deeply situated than the pisiform exostosis.

Two exostoses were also situated in the left meatus. One, about the size of a small pea, arose by a broadish base of attachment from the anterior wall; the other, the size of a small shot, arose from the posterior wall towards its lower part. The two exostoses almost touched in the middle of the meatus, so that in the living person, when the integument was in place, the passage must have been quite blocked up. The exostoses, both on the right and left sides, grew from that part of the wall of the meatus which was formed by the auditory plate of the expanded tympanic ring.

In consequence of this observation I was led especially to examine the specimens of artificially deformed crania in the Edinburgh museums, to see if similar exostoses were present in any of them.

In one, the adult skull of a flat-head Chenook Indian from the district of the Columbia River, in the Natural History collection in the Museum of Science and Art, I found the right external auditory meatus partially occluded by a broad based exostosis, which was elongated from without inwards, and grew from the posterior wall formed by the tympanic plate. On the left side a similarly shaped though smaller exostosis also sprang from the posterior wall; and much deeper in the meatus a linear shaped exostosis could be seen, which, from its position, was evidently attached to the same wall near the posterior border of the membrana tympani.

As these two crania, as well as those observed by Professor Seligmann, had been much altered in shape by artificial compression, the question naturally arises if the growth of the exostoses had been induced by the pressure to which the bones had been subjected during infancy. There is nothing in the appearance of these two skulls to bear out this supposition. Notwithstanding the deformity of the vault of the cranium, and a somewhat backward inclination of the squamous temporal, the zygoma and the parts around the meatus have preserved their normal form. Again, although Professor Seligmann found exostoses in as many as five out of six artificially deformed crania, which came under his notice, I have only seen the above two specimens, whilst seventeen other artificially deformed crania of North and South American Indians have been examined. At

the same time, I should say that, in at least three of these skulls the auditory meatus (though without any exostosis) was modified in shape from what one usually sees, for instead of being almost circular at its orifice it was antero-posteriorly compressed, so that the vertical diameter was markedly greater than the antero-posterior. I am not, however, prepared to ascribe this modification in the form of the orifice of the meatus to the artificial compression, for I have observed in several specimens of Peruvian skulls, which were not artificially deformed, a similar alteration in the form of the external meatus. In one in particular, a specimen from a tomb at Pachacama, now in the Natural History collection in the Museum of Science and Art, the entrance into the right external meatus was narrowed into a vertical slit. There would thus appear to be a tendency on the part of the aboriginal inhabitants of the American Continent to possess modifications in the configuration of the external auditory passage.

Professor Welcker has already pointed out that the growth of exostoses from the walls of the meatus cannot be regarded as a race character peculiar to American crania; and this conclusion is strengthened by the more extended series of cases recorded by Dr Barnard Davis. From the observations of the late Mr Toynbee,[1] in which he states that, out of 1013 diseased ears dissected, he found in fourteen cases bony growths from the osseous walls of the meatus, it would seem as if osseous tumours in the meatus by no means unfrequently come under the notice of the aural surgeon. It is therefore the more remarkable that crania exhibiting them *in situ* have not been more frequently noticed in our museums.

[1] *The Diseases of the Ear*, London 1860, p. 122.

THE ANATOMY OF THE QUADRICEPS EXTENSOR CRURIS. By W. Roger Williams, M.R.C.S., *Assistant Demonstrator of Anatomy at the Middlesex Hospital Medical College.*

The conflicting accounts of the quadriceps extensor cruris have induced me to make a careful investigation of the muscle, and the following is the result of my observations:—

Rectus femoris.—As the rectus approaches the pelvis it narrows into a strong strap-like tendon, about an inch broad, the surfaces of which are disposed in anterior and posterior planes in conformity with the rest of the muscle. At about 1½ inches in front of the anterior inferior iliac spine a change takes place, both in the disposition of the surfaces of the tendon and in its direction. This is the result of a twist, by which the anterior surface becomes internal, the posterior external; and the tendon is deflected in a direction downwards, backwards, and slightly outwards. It then *lies flat* along the upper part of the acetabulum; its inner surface being in contact with, and firmly fixed to nearly the whole extent of bone between the inferior curved line and the edge of the articular fossa. Traced backwards it follows the curve of the acetabulum, and spreads out into a number of tapering fasciculi, the longest of which are close to the edge of the articular cavity, and surround about half its circumference, being intimately blended with the cotyloid ligament and the capsule of the joint. This part is usually described as the reflected head. A strong process of fascia lata, springing from the ilio-tibial band, at a short distance below the insertion of the tensor fasciæ femoris, passes obliquely upwards and inwards to join the tendon of the rectus at the junction of its two heads of origin; it also spreads backwards over the outer surface of the acetabular tendon, to which it is very firmly adherent, being fixed above to the inferior curved line, and below blending with the capsule of the joint; so that it binds down the tendon most effectually. It is also attached to the anterior border of the ilium, between the inferior spine and the top of the acetabulum, as well as to a rough tubercle just above the

joint cavity. A rounded band of condensed areolar tissue connects the flexure of the tendon to the apex and outer surface of the anterior inferior iliac spine; and from this a falciform piece is prolonged to the anterior border, for about an inch above the inferior iliac spine. Seen from the front, this band appears to be the direct continuation upwards of the muscle; hence it is usually described as the straight head. The two heads are connected by the deep process of the ilio-tibial band, which, as it passes upwards, splits to enclose the acetabular tendon (before this is fixed to the bone); above the tendon these laminæ are attached to the iliac head and the inferior spine, being continuous with the falciform piece. The heads are also connected by a dense areolo-fatty tissue, situated between the two layers of this fascia.

It will be gathered from the above description, that the reflected head is not in any sense an accessory band as is sometimes implied; it is, indeed, the main tendon. On the other hand, the straight head, which is commonly regarded as the main tendon, is nothing but an accessory band of condensed fascia. Any one may convince himself of the truth of this, by making a complete dissection of the two heads of the muscle. The acetabular head (when its fascial covering has been removed), will be found of a shiny yellowish white appearance, being marked with fine longitudinal striæ and transverse creasings. It has a hard india-rubber like feel, and, in short, all the characters of true tendon. But the straight head, although when first uncovered it may have a tendon-like appearance, after a short exposure to the air, undergoes a peculiar pinkish-purple discoloration. This reaction is quite characteristic of condensed areolar tissue, for true tendon does not undergo the change. I have often found this fascial band sparsely pitted with irregularly placed areolæ containing small fat granules; and though some of its fibres usually have a longitudinal arrangement, the majority are heaped together without order. It is tough, but not hard and elastic, having the characters of condensed areolar tissue. By running the heads between the thumb and forefinger the continuity of the reflected head with the main tendon may be readily appreciated. This may also be seen (after detaching both heads and removing the muscle from the body), by laying

it flat on the table with the anterior surface upwards. In this position the reflected head straightens out, and appears as the direct continuation of the main tendon; whilst the iliac head projects from its side as a mere appendage.

This view also receives confirmation from the examination of the muscle in the fœtus. At about the sixth month only the acetabular head can be distinguished. The iliac head cannot be discriminated from the fascia of the part. At full term the acetabular head is as large as the main tendon, of which it is obviously the direct continuation; whilst the iliac head, though plainly visible, is relatively insignificant.

The evidence derived from the microscopical examination of the heads in the adult points to the same conclusion. For the fibres of the iliac head, when examined in water, have not the same regular arrangement as those of the acetabular head; and when the former were treated with acetic acid, a great number of yellow elastic fibres came into view, but when the latter were similarly treated, there was hardly a yellow fibre to be seen. So that, by this method alone, it was quite possible to determine with certainty from which head the tissue under examination had been taken.

Mr Hensman has called my attention to the fact, that in the flexed condition of the fœtal limb the acetabular head is not bent; it is then in a straight line with the rest of the muscle. With regard to the relative size of the two heads in adults, I have usually found the acetabular to be the larger. The size of the straight head is proportional to the muscularity of the subject; but the reflected head does not undergo a corresponding variation.

Hence, the difference between the heads is most marked in women, and the appearances just described are easiest of demonstration on the female subject.

The body of the muscle is spindle shaped; it is made up of fleshy and aponeurotic fibres, and the arrangement is as follows:—The upper tendon passing downwards spreads out into an aponeurosis, which covers the superior third of the muscle in front. From this a tendinous band is prolonged down its centre as far as the junction of the lower and middle thirds. This raphé is formed by an infolding of the inner edge of the aponeurosis, which, at about its middle, dips down into the fleshy mass;

below it is gradually lost amongst the fleshy fibres. It is placed edgewise, and with the exception of the anterior edge is entirely concealed by the muscular mass.

The superficial fleshy fibres arise from its sides in a penniform manner; they pass downwards and slightly backwards—the internal, inwards; the external, outwards—being finally fixed to the borders and adjacent part of the anterior surface of an aponeurosis occupying the deep surface of the muscle. The fibres springing from the lower end of the raphé, run a nearly longitudinal course to their insertion on the deep tendon; and those which arise from its posterior edge have a somewhat similar disposition. The fleshy belly ends at about 3 inches above the patella, being succeeded by a flat tendon, which narrows as it descends; and at about an inch above the knee-cap widens out into a triangular expansion, which blends with the other tendons of the great extensor, and is inserted into the front of the obliquely cut upper surface of that bone. For some inches above the tendon of insertion the edges of the muscle are usually tendinous; this is owing to the cropping up of the deep aponeurosis. The edges of the tendon of insertion give attachment to fibres of the external and internal vasti muscles, and it sometimes happens that these fibres are prolonged over the front of the tendon, forming a thin semi-adherent film. The tendon gives off expansions around the knee-joint, which blend with similar expansions from the vasti.

Traced upwards, this tendon expands into an aponeurosis, which covers the lower two-thirds of the deep surface, the upper one-third being fleshy; the muscular fibres passing from the deep surface of the superficial aponeurosis to the superficial surface of the deep aponeurosis, except near the margins where are the pennate fibres.

Some vessels and nerves enter its inner edge at about the middle, and at this spot the muscle readily splits into two laminæ. The anterior, comprising the raphé and the pennate fibres; the posterior, the deep aponeurosis and the stratum of longitudinal fleshy fibres above it. This will be at once appreciated by making a cross section at this level.

It is a common error to describe the rectus as a bipenniform muscle. This arrangement only exists superficially; on the

deep surface, both the aponeurosis and the fleshy fibres have a longitudinal disposition.

In a thin old woman the muscle weighed 2½ oz.; in a very muscular man 5½ oz.[1]

VASTUS EXTERNUS.—After the removal of the rectus, the muscular mass on the front of the femur does not at first sight present any very distinct evidence of subdivision. The descending branches of the external circumflex vessels, and the accompanying nerve, are the best guides to the anterior edge of the vastus externus. The position of these vessels along the upper edge of the muscle I have found remarkably constant. For about 5 inches above the patella this border is in close proximity to the rectus, and for this extent it is commonly aponeurotic. The edge at this place consists of two tendinous laminæ, between which runs an articular nerve for the outer side of the knee-joint, and the descending branches of the external circumflex vessels. Unless care is taken in raising this part of the muscle, the knife may slip into this interval, and by opening it up, the muscle may be almost completely split into two laminæ. A thin layer of fleshy fibres of the vastus externus is prolonged over this edge, and is fixed to the adjacent tendinous border of the rectus.

Above this the edge of the muscle is fleshy. Proceeding upwards, it at first inclines inwards, crossing the middle line of the limb for a little way, and then slopes outwards to the tubercle of the femur. This part of the anterior border is overlapped by the rectus. The posterior edge of the muscle is only free in its lower half; the upper half forming most of the attachment of origin. To define this border, place the limb with its outer surface upwards, and separate the external intermuscular septum, as far as possible, along the whole length of the muscle, but without dividing any of its fleshy fibres. At the lower part of the limb there is now visible an upper almost longitudinal set of fibres, which also incline slightly forwards, belonging to the vastus externus; these cross over a lower corrugated and loosely arranged set, which run obliquely downwards and forwards. In the sequel it will be shown that these deep oblique fibres belong to the outer part of the crureus. To bring into view the edge of the muscle, which is almost invariably tendinous, we must cut through a thin layer

[1] The gluteus maximus in these subjects weighed respectively 12½ oz. and 24 oz.

of fleshy fibres prolonged over it from the deep oblique set, as these are usually attached to it. Indeed, I have generally found these parts extensively blended.

Viewed *in situ* the muscle has a lozenge-shaped outline, its upper and lower extremities appearing as narrow processes. When thoroughly cleaned it has a loose baggy appearance, and is often thrown into longitudinal folds. The vastus externus forms a prominent mass on the outer side of the thigh, overlaying the crureus. It is the largest and most powerful division of the great extensor; owing to this predominance there is a natural tendency for the patella to be dislocated outwards.

The greater part of the superficial surface is occupied by an extensive aponeurosis, which covers over a deeper seated fleshy layer. This extends over the upper three-fourths of the muscle, with the exception of a band about 2 inches wide adjacent to the anterior border. If the attachment of this aponeurosis is traced backward to the bone, it will be found to correspond to that of the origin of the muscle.

Most of the superficial fleshy fibres pass from the unattached edge of this aponeurosis in a direction downwards, slightly forwards and inwards, to the upper surface of a tendon occupying the lower half of the deep surface. These fibres are fixed chiefly to the part of this tendon adjacent to the rectus muscle; and as we have before seen, some of them are prolonged to its edge. The fibres on the outer side of the limb, that pass downwards and forwards close to the unattached part of the lower border of the muscle, crossing over the deeper seated oblique fibres of the crureus, these narrow into a thick process, which is at first muscular on the surface, but as it nears the patella it becomes entirely tendinous, forming a flat pad about 2½ inches wide on the outer side of the knee-joint. This tendon is commonly more or less completely broken up into four or six parallel bands. It is thicker and stronger than the pad on the inner side of the joint, and gives off fibrous expansions, which blend with those from other muscles, forming a fibrous capsule for the knee-joint, fixed below to the head of the tibia.

The capsule formed by the expansions of these muscles is almost entirely separable from that formed by the fascia lata. The front edge of the tendon is continuous with the anterior

border of the muscle. It inclines inwards between the tendons of the rectus and crureus; and in the median plane of the limb, at about an inch above the patella, blends with the aponeurotic edge of vastus internus, which has taken a similar course from the inner side. The two tendons then fuse with one another, as well as with the rectus in front and the crureus behind, forming in this way the common tendon of insertion. The rest of the vastus externus tendon is inserted into the upper half of the outer border of the patella, whilst the aponeurosis prolonged from it is fixed to the lower half.

On detaching the tendon its deep surface is seen to be immediately in contact with the synovial membrane of the joint.

Having cut the tendon from the patella and freed the lower border, the muscle should be detached by raising it from below upwards. Just above the joint its aponeurosis will be found extensively blended with the subjacent fleshy fibres of the crureus. This occurs again at about the middle of the muscle, near the posterior border; and at some distance above this by its fleshy part there is another adhesion. The amount of union between this and the subjacent muscle varies greatly; but it is usually extensive. Indeed, I have always found these two muscles more intimately united together even than the vastus internus and the crureus. To complete the detachment it only remains to cut through the attachment of origin. On examining the cut attachment, it will be seen to consist of two laminæ blended together. Externally there is a thin tendinous piece continuous with the superficial aponeurosis; internal to this is a thick fleshy layer. The lower 3 inches of the attachment is almost entirely aponeurotic.

The muscle arises by an attachment extending from the tubercle at the top of the spiral line, along the anterior border of the great trochanter, internal to the tendinous insertion of the gluteus minimus. It then turns round the tendon of the gluteus medius, at the anterior inferior trochanteric angle, and continues its course along the inferior border of the great trochanter, as far as its middle. These two pieces are placed at right angles to one another. Leaving the great trochanter at the middle of its lower border, the muscle is fixed to the outer division of the upper bifurcation of the linea aspera, and to the

outer part of the gluteal ridge, which is merely a thickening of this part of the linea aspera. It is also blended with the tendon of insertion of the gluteus maximus; and where the two muscles glide over one another, a bursa intervenes. For the rest, the line of origin follows the outer lip of the linea aspera, being attached to it as far down as the commencement of its lower bifurcation, a point rather below the middle of the femur. The muscle also takes origin from that portion of the external intermuscular septum adjacent to the linea aspera.

Most of the fleshy fibres arise from the deep surface of the superficial aponeurosis; whilst the muscle is *in situ*, they are completely concealed by it. The thickest part of the attachment is round the great trochanter, where it measures half an inch or more. Below this it is much narrower. The upper part of the origin is usually separated from the adjacent attachment of the crureus by a strip of bare bone, about an inch wide. This is often diminished, and may be quite obliterated, by the encroachment of one or other, or both muscles. In such cases they are fused together. The muscle exposed by the removal of the vastus externus comprises the greater part of the crureus.

From the tendon of insertion a broad aponeurosis spreads upwards over the lower half or two-thirds of its deep surface; where this was blended with the crureus, at the outer side of the thigh, the remains of the fleshy fibres are still visible. The rest of the deep surface is occupied by fleshy fibres, disposed in two layers. A deep set, which arise from the bone around the great trochanter, made up of large, coarse, parallel fasciculi, having a direction downwards, forwards, and inwards. In passing downwards some of these are blended with the crureus; others are inserted into the under surface of the deep aponeurosis for its upper third. This layer usually separates with the vastus externus, of which it appears to be a part. Sometimes, however, I have found it inserted entirely into the surface of the crureus, at the junction of its upper and middle thirds, being unconnected with the vastus externus except at its origin. In these cases it was difficult to assign it to either muscle, for it seemed to constitute a distinct piece, which may, for the sake of convenience, be called the vasto-crural slip.

The superficial set of deep fibres are more numerous than the

other. They arise from the deep part of the superficial aponeurosis, and are inserted into the upper surface of the deep aponeurosis. On making a cross section through the middle of the muscle, it appears to be made up of two laminæ, which are imperfectly blended at this place. In a thin old woman the muscle weighed 7 oz.; in a very muscular man, 11 oz.

VASTUS INTERNUS.—The standard descriptions of the muscular mass laid bare by the removal of the vastus externus are very conflicting, I have found the strand along the inner side of the femur, which I shall call the vastus internus, readily separable from the rest.

At the middle third of the thigh the thick fleshy edge of the vastus internus may be readily distinguished from the aponeurotic surface of the crureus. A line drawn from the tubercle at the middle of the spiral or anterior intertrochanteric line, inclining downwards and slightly outwards to the middle .of the upper border of the patella, will define accurately the thick anterior border of the vastus internus. This tubercle at the middle of the spiral line has not hitherto been noticed by anatomists. In well marked bones it is always distinct. I have ventured to call it the *inferior cervical tubercle*, in contradistinction to the tubercle at the top of the spiral line, which may be spoken of as the *superior cervical tubercle.* It corresponds to the attachment of the lower end of the inner arm of Bigelow's inverted Y ligament, just as the upper tubercle does to the outer arm of this ligament.

The upper two-thirds of the anterior border is fleshy, and is often, but by no means invariably, united to the fleshy fibres of the crureus. Its lower third is tendinous, simply resting on the superficial aponeurosis of the crureus. The posterior border of the muscle corresponds to the attachment of origin; its upper two-thirds is aponeurotic, forming part of an aponeurosis which spreads over the adjacent surface of the muscle to within a few inches of the anterior border. The upper limit of the aponeurosis may be indicated by a line drawn from the inferior cervical tubercle to the groove for the femoral artery. Fibrous bands from the adductors forming Hunter's canal, are fixed to this aponeurosis near its back part, rather below the middle of the thigh. Adherent remains of this structure are now visible. The

rest of the surface is muscular, with the exception of a narrow aponeurotic strip adjacent to the tendinous part of the anterior border. At about 4 inches above the knee-joint, the tendinous front edge of the muscle inclines outwards, between the tendons of the rectus and crureus, meeting the tendinous edge of the vastus externus in the middle line, at a short distance above the patella, the two blend with one another as well as with the rectus and crureus, forming the common tendon of insertion in the way previously described.

The fleshy fibres pass obliquely downwards, forwards, and outwards. They are, for the most part, fixed below to the superficial surface of a long narrow tendon, which runs along the deep surface, close to its anterior border, for its lower half or more. Of these fleshy fibres, some, which are adjacent to the rectus tendon, are attached to its edge. The lowest fibres have an inclination forwards, more nearly horizontal; they pass directly to the inner border of the patella, terminating inferiorly in a free edge.

To detach the muscle we must first free the anterior edge. It is best to *begin below,* just above the patella, for here the tendinous under surface of the vastus internus rests on the aponeurosis of the crureus and the two are readily separable. The fleshy part of this border is commonly blended with the crureus; and to free it, muscular fibres must be cut through. But it often happens, even at this place, that the two muscles are simply contiguous, without being fused; in these cases a complete separation is easily effected without any division of fleshy fibres.

The lower end of the vastus internus is to be detached from the patella; and the mass is to be thrown inwards. In this way the whole length of the inner surface of the shaft of the femur is exposed; it is bare and quite devoid of muscular attachment. Running along the edge of the crureus, for its lower three-fourths behind the line of union of this muscle with the vastus internus, is a long slender nerve, derived from the upper branch to the vastus internus; it is distributed *to the subcrureus* and to the *upper part of the synovial pouch of the knee-joint.* I am not aware that it has been previously described. It forms a useful guide for separating the vastus internus from the crureus; and is the third articular twig to the knee, derived from the muscular branches of the anterior crural.

Having freed the anterior border, to remove the muscle we must cut through the attachment of origin. This commences above, at the inferior cervical tubercle, and passes downwards along the lower half of the spiral line, in front of the fleshy fibres of the iliacus, to join the inner lip of the linea aspera, from the whole length of which it arises as far down as the groove for the femoral artery. At this place its attachment to the bone ceases. Along the linea aspera the vastus internus also arises from the insertions of the adductor muscles. For this extent the attachment is bilaminar; thus there is a thin aponeurotic part corresponding with the origin of the superficial aponeurosis, as well as a deeper layer of fleshy fibres covered in and concealed by it. This fleshy layer, however, is limited to the immediate proximity of the line of origin. Its fibres do not encroach to any extent on the inner surface of the shaft, which is left quite bare, and is simply overlapped by the muscle. Below the groove for the femoral artery the attachment consists entirely of fleshy fibres. These spring from the whole length of the rounded tendon of the adductor magnus; and from the upper concave surface of the fibrous membrane, uniting it to the inner division of the linea aspera.

The insertion is with the common tendon into the front of the inner half of the base of the patella; but the lower fibres pass directly to the inner border of this bone. As pointed out by Cruveilhier, an aponeurosis is prolonged from this part to be inserted just below the inner tuberosity of the tibia, and into the internal lateral ligament to which it forms an accessory band.

The lower expanded end of the muscle is thin and concave to the knee-joint, which it overlays. Its deep subaponeurotic surface being in contact with the synovial pouch.

If we spread out the muscle on the table, it will be seen to have an elongated triangular shape. The apex was fixed above at the inferior cervical tubercle, and the base below at the patella. The anterior edge is much thicker than the attached part. A strong tendon about 1½ inches wide spreads along the lower half of its deep surface, close to the anterior border. The rest of the deep surface is fleshy; the fibres running downwards and forwards towards the anterior border. They arise from the under surface of the superficial aponeurosis, and are inserted into the edge as

well as the adjacent part of the upper surface of the deep tendon.

It will be seen from this description that I have not found the vastus internus blended with the crureus to the extent usually stated.

I have never found sufficient union to justify the supposition that the two form but one muscle; and I do not consider this mode of description at all in accordance with the nature of things. It is true that the upper half of the front edge of the vastus internus is not uncommonly fused with the adjacent part of the crureus. But this is the whole extent of the union, and it is by no means constant, for even here the two muscles are often quite separable. The nerve to the subcrureus indicates a real separation. At the lower part of the thigh the two muscles are always distinct, and it is important to notice that their aponeuroses are never blended. The vastus externus and the crureus are much more extensively united than the latter muscle and the vastus internus; yet no one has been bold enough to assert that they form a single muscle. They are, indeed, obviously distinct; and it follows that the crureus and vastus internus are much more so. Triceps femoralis is therefore a misnomer. The inferior cervical tubercle marks the limit of the upper attachment of the crureus and vastus internus. Here the edges of these muscles—whether fused or separated—are contiguous; that of the vastus internus being in front of and slightly overlapping the crureus. The muscular mass exposed by the removal of the vastus externus has been described as forming a *continuous* lamina or mantle, overlaying and covering up a deeper set of fibres. But such a simile is very misleading, and if we allow it for a moment, it must be admitted that the mantle is *not a continuous one*. Like other mantles it consists in front of two flaps, which, although they are approximated and may be fastened, nevertheless, readily come open. In this sense the simile is less objectionable, and it may be said that the mantle-flap—vastus internus—overlaps the mantle-flap crureus, and is fastened to it at the upper part.

In a thin old woman the muscle weighed 5 oz.; in a very muscular man, 7¾ oz.

The CRUREUS is the muscle now left covering the anterior and

outer surfaces of the femur. The lower two-thirds of its anterior surface is covered by an aponeurosis prolonged upwards from the common tendon of insertion. This aponeurosis is narrow below when it is placed in the middle line of the limb; but above it spreads out occupying the whole of the anterior and part of the outer surface. The rest of the mass is fleshy. The fibres of the upper third pass nearly vertically downwards, and are attached to the superior edge and adjacent part of the upper surface of the aponeurosis. Those of the outer side pass obliquely downwards, forwards, and inwards, being fixed to the whole length of the outer border and adjacent part of the upper surface of the aponeurosis. Most of the crureus is overlaid by the vastus externus; the two muscles being extensively united. Its inner edge is overlapped by the vastus internus; and along the upper half of the thigh they are commonly blended. Between the edges of the vasti muscles a portion of the aponeurosis is left uncovered. The deep surface of the rectus overlays this.

It will be remembered that some of the fleshy fibres on the outer side of the thigh, just above the knee, are quite subcutaneous, being placed altogether behind the posterior edge of the vastus externus. All these fleshy fibres form a surface-layer of from a quarter to half an inch thick; on cutting into this in front by a median longitudinal incision, it will be found to cover over a deeper muscular layer, from which, at its origin, it is usually separated by a bare interval of bone about an inch wide. This passes transversely across the front of the shaft from the inner side, where it is continuous with the bare internal surface, obliquely down the outer surface for about three inches. The line of origin of this surface-layer passes outwards, from the inferior cervical tubercle, across the anterior surface of the shaft. Thence it inclines obliquely down its outer surface to the lower end of the gluteal ridge; being continued downwards along the outer lip of the linea aspera and the adjacent part of the external intermuscular septum. For this extent it is blended with the vastus externus, as well as with the layer of the crureus inferior to it. Below the inferior bifurcation of the linea aspera the fibres cease to arise from the bone; but they are still blended with the deeper layer, and continue to arise from the inner sur-

face of the external intermuscular septum, close to its attachment to the outer division of the linea aspera.

Having turned aside this layer we should make a similar incision into the deeper fibres thus exposed. These are separated from a still deeper set, which they completely cover in, by a bare interval similar to the first. This layer arises from the bone by a corresponding arched process separating the two bare intervals.

On dividing the third set of fibres they will be found separated from a fourth layer by just such another bare interval; and below the fourth arch the fibres of the subcrureus arise.

Thus the muscle may be said to consist of four laminæ placed one over the other; separated above, at their origin, by intervals of bare bone, but fused together below.

Each layer arises entirely by fleshy fibres in the form of an arched process, which extends from the inner border of the shaft transversely across its front, and then obliquely down its outer surface for a short distance, to the linea aspera, where it blends with the adjacent layers of the crureus, the vastus internus, and the external intermuscular septum. Each process is made up of a number of parallel arched lamellæ, placed one over the other, so that, when these arches are so much increased in size as to encroach on or obliterate the based intervals, these lamellæ still retain the typical arched arrangement.

I have ventured to call these processes of origin the *Crureal Arches.* The lowest is usually situated about 5 inches above the trochlear surface of the femur. The fibres of each layer pass nearly vertically downwards, and are inserted into the under surface of the deep aponeurosis in the same order as they arise. On the outer side some of the lowest fibres of the surface-layer are fixed directly to the outer edge of the patella. The lower part of each layer blends with the surrounding parts of the muscle, and along the outer side of the femur the layers are again extensively fused. Some of the fibres derived from the lowest arch on each side are inserted into the upper part of the synovial pouch.

The crureal arches may be shown very well by pulling the muscle gently upwards and along the inner border, seeking for the bare interspaces where these are continuous with the inner

surface of the shaft; a little separation with the handle of the scalpel renders them distinct.

The subcrureus is evidently the rudiment of a fifth arch. It usually consists of two or three pairs of fleshy strips, one or more of which are very often imbedded in the fatty mass covering the front of the bone, for about four inches above the articular surface. Behind the tendon of the crureus, for an inch or more above the patella, a bursa is usually placed, which, in the majority of cases, communicates by a large opening with the synovial cavity of the knee. In a few instances I have found this bursa quite distinct. This part of the tendon is blended in front with the vasti and rectus, forming the common tendon of insertion.

As insisted on by Cruveilhier, this is inserted, not into the upper *border* of the patella, but into the *front* of its obliquely cut upper surface. Similarly the ligamentum patella is fixed to the *front* of the apex. In this way the axis of the tendon is removed somewhat from the centre of motion of the joint, so that the muscle acts at the greatest advantage. At the suggestion of Mr Hensman, I have been led to consider the course pus would be likely to take in the event of an extravasation, such as might result from the rupture of a suppurating knee-joint. It follows from the description that the line of least resistance would be along the inner side of the femur, as far upwards as the small trochanter, and thence outwards, in front of the bone, along the bare intervals between the layers of the crureus, to the outer side.

This will explain the rapid and wide spread of abscesses of this kind, as well as the effusion of pus which sometimes takes place between the muscular planes.

In a thin old woman the crureus weighed 8 oz.; in a very muscular man, 12½ oz,

In conclusion, my best thanks are due to Mr Arthur Hensman, Senior Demonstrator of Anatomy at the Middlesex Hospital, for many valuable suggestions, and for kind assistance in correcting the manuscript.

OBSERVATIONS ON THE INFLUENCE OF AN ELECTRO-MAGNET ON SOME OF THE PHENOMENA OF A NERVE. By Professor M'KENDRICK, *University of Glasgow.*

1. WHILST observing the phenomena produced by the influence of a magnet on the electric discharge in gases, it occurred to me to examine the actions of a living nerve in a magnetic field. As I had no powerful permanent magnet in my possession, I employed a horse-shoe electro-magnet of soft iron, each limb being 7 inches in length, and the diameter of the bar 1¼ inches. The battery employed consisted of twenty of Sir William Thomson's tray-cells, united in "multiple arcs" of ten. A key was interposed in the circuit so as to make and break the current of the electro-magnet at pleasure. On the poles of the electro-magnet, I placed two flat rectangular pieces of soft iron, each 2½ inches long by 1¼ inches broad. By moving these pieces on the poles, whilst the core was unmagnetized, the extent of the magnetic field could be varied at pleasure. The magnet and other portions of the apparatus were insulated by glass plates, and the wires leading the current from the battery to the magnet were thick copper wires insulated by gutta-percha.

2. Having prepared the limb of a frog in the method usually followed in physiological experiments, the sciatic nerve was stretched from the one pole of the electro-magnet to the other, touching both. It was then found that, on closing the key in the circuit of the electro-magnet, there was sometimes a contraction of the limb, and that there was usually a contraction on opening the key,—at all events, whilst the nerve retained its irritability, there was contraction either in closing or on opening the current. This happened when the nerve was touching the poles of the electro-magnet, and it might be supposed that it was due in some way to an escape of a portion of the current through the nerve. To test this, I connected each of the poles of the electro-magnet (the flat plates above referred to) with a very sensitive reflecting galvanometer standing at a distance of 12 feet from the electro-magnet, and found that, when the current

of the electro-magnet was closed and opened, there was a deviation of 3 degrees (and the galvanometer was so sensitive that merely touching the terminals drove the spot of light off the scale). Consequently, the current passing into the galvanometer circuit was extremely small. To ascertain whether the galvanometer current might not be due to an inductive effect of the electro-magnet, I laid a bit of copper wire from the one pole of the electro-magnet to the other, so as to complete the galvanometer circuit, and then it was ascertained that there was the same amount of deviation of the needle on opening and closing the circuit of the electro-magnet. Thus, it would seem that on opening and closing the circuit of the electro-magnet, a nerve resting on its poles is irritated, and a sensitive galvanometer connected with its poles is also very slightly affected. Both of these effects are probably due to an induction current developed instantaneously in the nerve and in the galvanometer circuit at the moment of opening and of closing the circuit of the electro-magnet.[1]

In these experiments, the nerve, as above stated, was so placed as to touch the moveable flat plates on the poles of the electro-magnet. Contractions were also obtained when the nerve was laid on the naked poles of the electro-magnet, and even when it was placed *on one pole*. In the latter instances the electro-magnet evidently directly stimulated the nerve, probably by exciting in it a brief induction current.

3. In another series of experiments, a freshly prepared nerve was laid on the poles, so that about 1 inch of nerve stretched from pole to pole. By means of the key in the circuit of the electro-magnet, the latter could be made magnetic and non-magnetic at pleasure. With the view of ascertaining whether the excitability of the nerve was in any way affected by its position between the magnetic poles, I touched it with a copper wire whilst the key was open, and consequently the electro-magnet was not acting, and immediately there were contractions of the limb; on closing the key so as to form the electro-magnet, the same stimulation produced no effect. This observation was made many times, and the conclusion first arrived at was that

[1] Clerk Maxwell, *Electricity and Magnetism*, vol. ii. p. 180.

the magnetic influence diminished the irritability of the nerve. To check this theory, several test experiments were made. Every part of the apparatus was carefully insulated, and the operator stood on a stool having glass legs. When he touched the nerve with the copper wire, it was then found that no contractions took place either whilst the electro-magnet was magnetic, or whilst it was not. But when the operator placed his hand on the table, and touched the nerve with the wire, contractions again took place. To vary the observation, the key in the electro-magnetic circuit was left open, and an assistant was sent to the battery, about ten yards off, but in the same apartment, and he was told to make and break at the battery, on the word of command. It was found that when the current was closed at the battery, the operator, standing on the floor, could excite the nerve by a copper wire, but when he stood on a stool with glass legs, he could not do so. When the current was opened at the battery, the operator could still influence the nerve two or three times, whilst standing on the floor, and then the influence passed off. The inference, therefore, was that a branch current passed from the battery through the floor and through the body of the operator, and that this current irritated the nerve. When, however, the current of the battery was sent through the electro-magnet, irritation of the nerve by the copper wire produced no effect. Possibly one or both of two events followed the forming of the current of the electro-magnet:—(1.) The branch current just alluded to may have disappeared or been very much weakened; and (2) the current derived from the poles of the electro-magnet, the effects of which I have described in the second paragraph of this paper, may have had some influence on the irritability of the nerve. After many attempts, however, I have not been able to detect the existence of the supposed derived current except my means of the nerve *in the presence of the electro-magnet.* If I removed the nerve from the poles of the electro-magnet, and placed it in a similar position over the two rectangular pieces of soft iron above mentioned, the two pieces resting on a granite block, touching the nerve with the copper wire produces no effect. Again, if a feeble continuous current passed from one pole of the electro-magnet, through the nerve to the other, the effect ought to be, in accordance with the law of

electrotonus, increase of excitability (katelectrotonus) instead of its diminution. As, however, the nerve became less excitable during the action of the electro-magnet, the effect could not be owing to the passage of a feeble current through the nerve, from pole to pole of the electro-magnet.

But another explanation might be offered of these results. There could be no doubt that a branch current found its way from the floor, through the body of the operator, inasmuch as when the nerve was touched with a copper wire, vigorous contractions took place, whereas, when the body of the operator was insulated, no such effect was produced. These phenomena were observed when the key of the circuit of the electro-magnet was open, and they disappeared when the key was shut; that is, they took place only when the current did not flow through the coil of the electro-magnet. Hence, it might be supposed that the current could pass more readily through the coil of the electro-magnet, than through the floor and the operator. The difficulty attending this explanation is that, when the nerve was laid on the metal plates, at a distance, say 8 or 10 inches, from the electro-magnet, touching it with the copper wire, either whilst the electro-magnetic circuit was open or shut, caused no contractions. The phenomena only occurred when the nerve lay on the naked poles of the electro-magnet, or on the flat plates placed on these poles, and the inference, therefore, is that the presence of the electro-magnet was necessary. It would therefore appear that *a portion of nerve stretched between the poles of an electro-magnet, so as to touch each, will not excite contractions in a muscle when touched by a copper wire during the passage of the current through the wire of the electro-magnet.*

4. In the preceding experiments, the nerve actually touched the poles of the electro-magnet. In other experiments, the nerve was laid on a thin glass plate, placed between the flat iron plates before described, but without touching either plate, and it was so arranged that it lay at right angles to a line joining the two magnetic poles. Thus, the nerve fibres would conduct in a direction at right angles to the magnetic lines of force. No satisfactory results were obtained, but enough was observed to show that the nerve was affected. Occasionally the muscle contracted.

I intend continuing these researches with the aid of a powerful electro-magnet in the Physical Laboratory of the University of Glasgow. It appears to be highly probable that nervous activity may be affected by magnetic action, and the experimental problem is to ascertain the conditions in which this may be done. At present, I merely state the facts observed, without entering upon a discussion of how they may be interpreted.

ON THE ACTION OF ANÆSTHETICS. Reported by Professor M^cKENDRICK, *University of Glasgow*, on behalf of the Committee.

AT the meeting of the British Medical Association in Manchester in 1877, a committee was appointed to investigate the action of anæsthetics. The committee consisted of Dr Coats, Pathologist to the Western Infirmary, Glasgow; Dr Ramsay, Assistant to the Professor of Chemistry; and myself. Since that date, the committee has been investigating the subject, and they have presented the following preliminary report to the Scientific Grants' Committee of the Association.

The present is intended merely as a provisional report, and no attempt will be made to give details of observations.

Two lines of inquiry soon opened themselves to us: first, to discover wherein the special dangers of chloroform consist; and, second, to try if some anæsthetic agent could be found which would avoid these dangers. We have also kept in view the investigations of the physiological action of anæsthetics in general, and the collection of evidence from the profession regarding the value and dangers of the anæsthetics at present in use.

In the first of these lines of inquiry, the much vexed question of the effects of chloroform on the respiration and the heart presented itself. Without going into detail, we may say that it soon became apparent to us that chloroform administered to dogs and rabbits has a disastrous effect on the respiratory centres; it is easy to kill one of these animals by pushing the chloroform till respiration is paralysed. In observing the state of the heart during these experiments, it could often be determined by auscultation that its contractions were maintained after respiration had ceased. It was apparent, however, that, even when failure of respiration was more directly the cause of death, the heart was to some extent simultaneously affected; and there were even cases in which the heart appeared to fail at least as soon as, if not before, the breathing. Considering these facts, and bearing in mind that failure of the heart is often asserted in the reports of death from chloroform, we devised a method of

experimentation by which respiration would be eliminated, and the effects of chloroform on the heart observed apart from that complication.

In the frog, we have an animal in which the movements of respiration are not necessary to life, so far as the heart is concerned, as that organ continues beating long after these movements have ceased. After exposing this animal to the vapour of chloroform under an inverted jar till it was anæsthetised, we exposed the heart by cutting the sternum in the middle line. The animal being again replaced under the jar, it was found that the heart became rapidly weaker, till it ceased beating. A similar experiment with ether showed a very different result. The exposed heart continued vigorously beating for a considerable time—in fact, as long as the experiment was continued.

With a similar view, a method was devised for warm-blooded animals. Rabbits were first used, and afterwards dogs. The animal was first anæsthetised; then the trachea was opened, a tube introduced, and artificial respiration begun by means of a double-acting pump (one cylinder forcing air in and another sucking it out). By an arrangement of India-rubber tubes, chloroform or any other anæsthetic could be introduced in the circuit between the pump and the trachea. It is to be understood that the air passes into the animal's lungs saturated with the vapour of the substance used. After artificial respiration had been set going, the heart was exposed by an incision in the middle line, which was carried by a pair of blunt scissors or bone-forceps through the ensiform cartilage and lower part of the sternum. This was effected generally with no serious bleeding. It soon became apparent that when chloroform is given in this way there is at once a most serious effect on the heart; the right ventricle almost immediately begins to distend, and the heart presently stops with the right ventricle engorged with blood. The heart had often, in the case of rabbits, virtually come to a standstill within a minute of the introduction of cloroform by the method described. The contrast was most striking when ether was used instead of chloroform; the other steps in the experiment being the same. Ether may be given for an indefinite period without interfering with the heart. We kept up artificial respiration with ether in the circuit for an hour, not including

twenty minutes occupied in producing anæsthesia, and at the end of that time the exposed heart was beating as vigorously as at first.

It was obvious, therefore, that apart altogether from the respiratory centres, chloroform has a disastrous effect on the heart, while ether has no such effect. While presenting in this respect an enormous advantage over chloroform, it was yet apparent that ether has some great disadvantages. The chief of these is the tardiness of its action. In comparative experiments with rabbits, in which the anæsthetics were given on a towel, it appeared that with chloroform complete anæsthesia was produced in about three minutes, while in the case of ether it took fifteen to twenty minutes, although the cloth was kept saturated. It occurred to us, therefore, to endeavour to find an agent which should be as potent an anæsthetic as chloroform, yet affect the heart and respiration as little as ether.

In testing the various agents used, we employed the methods described above. We administered them to animals, and watched the effects on respiration. We used the method on frogs by which the effect on the heart could be observed; and, in the case of some of them, we performed the experiment on rabbits and dogs, using artificial respiration and exposing the heart. It may here be remarked, that in these experiments the anæsthetics were given intentionally in large doses, because, if any substitute for chloroform is to be found, it must be one which may safely be given in exceptionally full doses. The following substances were administered.

Benzine (C_6H_6) was used with the frog. Its effects were nearly as slow as that of ether, and it produced struggling; weakening of the heart was apparent, but not so great as with chloroform.

Acetone (C_3H_6O) produced only slight anæsthesia in the frog, even after prolonged administration.

Pyrrol (C_4H_5N) produced anæsthesia in frogs with considerable less rapidity than chloroform, but great excitement and muscular spasms took place before complete anæsthesia. Administered to three young rabbits subcutaneously, it produced convulsive movements, chiefly of the jaws and fore paws. Anæsthesia in these rabbits was doubtful.

Bichloride of methylene (so-called, but, as it has not a definite

and constant boiling point, it is obviously a mixture; reputed formula CH_2Cl_2). With frogs, it was found that the heart became quickly affected, and soon stopped. With rabbits, respiration rapidly deteriorated and stopped while the heart was still beating. In an experiment with artificial respiration and exposure of the heart (as described above), the heart was weakened and soon stopped, but not so rapidly as with chloroform. As in the case of chloroform, the right ventricle became enormously distended—the first sign of paralysis being the commencement of this distension.

Amylene (C_5H_{10}) was administered to rabbits both by cloth and subcutaneously. No anæsthetic effect was produced.

Butyl chloride (C_4H_9Cl), administered to rabbits, affected respiration, but not very rapidly. In experiments with exposure of the heart, the cardiac pulsations became weaker, and ceased altogether after some time. In one experiment it was noted that, almost immediately after complete anæsthesia, the respirations became shallow and soon stopped.

Ethene dichloride (formerly named ethylene dichloride, or Dutch liquid, $C_2H_4Cl_2$) produced convulsive movements of both extremities, continuing up to death. There was no anæsthesia up to the commencement of the convulsions.

Methyl chloride (CH_3Cl), which boils at the ordinary temperature, was obtained in alcoholic solution in a sealed tube, and allowed to boil off into a funnel, into which the muzzle of a rabbit was inserted. After somewhat prolonged use, there was not any abolition of reflex action, and the animal almost immediately recovered. The only effect was slight drowsiness.

Ethyl chloride (C_2H_5Cl, boiling at 12° C. = 53·6° Fahr.) administered to rabbits in the same way as the above, produced rapid anæsthesia; but in one case the respirations soon stopped, and in another, when air was admitted more freely, general convulsions occurred.

Nitrous ethyl ether ($C_2H_5NO_2$) produced great excitement and convulsions, almost immediately followed by cessation of respiration.

It is apparent that the above substances all present disadvantages which render them unsuitable for general use as anæsthetics. There remain two agents, the actions of which are

more promising. These are isobutyl chloride and ethidene dichloride.

Isobutyl chloride (C_5H_9Cl).—1. *Experiments on frogs.*—When it was administered under a glass jar, complete anæsthesia occurred in about five minutes. The heart was then exposed, and it was observed for thirty-five minutes, during which period its contractions were perfectly vigorous. 2. *Experiments on rabbits.* When it was administered with a cloth, anæsthesia was produced in three to five minutes. It was continued after anæsthesia for nearly half-an-hour without any interference with respiration. 3. *Experiments on dogs.*—It was administered on cloth; anæsthesia was produced in four minutes. It was continued for half-an-hour, and respiration was unaffected, except slight occasional stertor.

Ethidene dichloride ($C_2H_4Cl_2$, an isomeride of ethene dichloride, produced from aldehyde).—1. *Experiments on frogs.*—Administered as before. The exposed heart continued beating slowly but regularly throughout the experiment, which lasted, in one case twenty minutes, and in another twenty-six minutes. Anæsthesia was produced in four or five minutes. 2. *Experiments on rabbits.*—It was given on cloth as usual. Anæsthesia was produced within four minutes. On one occasion respiration stopped, but soon recommenced. In experiments with artificial respiration and exposure of heart, the cardiac contractions continued vigorous throughout, the observation being continued for forty minutes from the first administration.

3. *Experiments on dogs.*—It was administered on cloth. Anæsthesia was produced in two to three minutes. In one case, anæsthesia was accompanied with some excitement manifested by squeaking; the animal was a young puppy. In another case, a large dog was kept fully anæsthetised for half-an-hour without the slightest failure of respiration or heart. The anæsthesia in this case was very rapid, and the administration was intentionally pushed with successive doses at short intervals, as evaporation took place. The recovery was rapid, and the animal manifested remarkably good spirits.

Two experiments were made on dogs, in which the heart was exposed, artificial respiration being kept up. No failure of the heart's action was observed, although the air passing into the lungs was saturated with the vapour of the substance. There

was complete anæsthesia. On quickly removing the bottle containing ethidene dichloride and substituting chloroform, the right side of the heart began almost immediately to become distended and to be dark in colour, and the activity of the heart rapidly failed. The contrast between the effects of the two substances on the heart was most striking. Practically, a dog will live for a lengthened period in a state of complete anæsthesia under the influence of ethidene dichloride, whilst it will die in a short time when chloroform is used.

It is worthy of observation that two substances, butyl chloride and isobutyl chloride, which have the same chemical formula, exhibit such different actions. The same contrast is seen in the actions of ethene dichloride and ethidene dichloride, which are also isomeric. The first of these produced severe convulsions, while the second promises to be an excellent anæsthetic without any convulsive effects.

We purpose continuing similar researches on substances which, from their chemical relations, hold out the hope of being serviceable. It will now be necessary to test the effects of the two substances whose results seem promising, and of any others of similar value, on the higher animals and on man.

With reference to the physiological action of anæsthetics, our attention has been mainly occupied with three inquiries, viz.; 1. The changes, if any, produced in the gases of the blood; 2. The changes effected in the gases of respiration; and 3. The effect of anæsthetics on nervous conduction and on mental phenomena as observed on man. All of these experiments have been of a very laborious character, involving the use of complicated apparatus, and the methods employed can yield satisfactory results only after considerable practice.

1. *The Effect on the Gases of the Blood.*—The blood was collected by means of a graduated tube filled with mercury and provided with a glass stopcock at each end. The upper end was placed in communication with the aorta or the inferior vena cava of a rabbit (immediately after it had been deeply anæsthetised) by means of a cannula, and by opening the stopcocks the blood flowed in at the upper end, replacing the mercury, which escaped at the lower extremity of the tube. It was thus possible to collect the blood without any admixture of air. The small portion

of the tube above the stopcock was then washed and filled with a boiled solution of salt, and attached by an India-rubber tube to the tube entering the receiver of a Pflüger's air-pump. The lower end of the tube containing the blood was then inserted in mercury. On opening the stopcock of the receiver and those of the tube containing the blood, the mercury in the vessel below displaced the blood, which flowed into the exhausted receiver, frothing and evolving gas. The gas was collected in the usual manner, and carbonic acid and oxygen were successively estimated by known methods. Some boiled solution of tartaric acid was then allowed to enter the receiver, and displaced a further quantity of carbonic acid, which was in its turn collected and estimated. A sufficient number of reliable experiments have not as yet been made to permit our giving results.

2. *The Effect on the Air breathed.*—The gases of respiration were analysed as follows: The animal was placed in a tin box with glass sides, provided with a lid of thick brass plating above, fitting over a square hole, and secured tightly by means of a washer of India-rubber and eight strong screw-nuts. Very great difficulty was experienced in procuring an air-tight joint, but the above means proved the best. Air deprived of carbonic acid by passing through potash solution, and then dried over sulphuric acid, entered the box by means of a tube at one side, and was drawn off at the other through a tube filled with calcium chloride, and then passed through a set of bulbs filled with solution of caustic potash. The increase of weight of the bulbs in a given time gave the amount of carbonic acid expelled. An attempt was also made to estimate oxygen by passing the air after absorption of carbonic acid over a strong solution of ammonia; enough of that gas is carried over to insure the combination of all the free oxygen with the hydrogen of the ammonia, when the mixture was passed over red-hot copper. Caustic baryta was used to absorb the water formed. The residue consists of a mixture of ammonia and nitrogen; and, after removal of ammonia by sulphuric acid, the remaining nitrogen is so pure that it does not tarnish melted sodium when a stream is directed against it.

The amount of carbonic acid accordingly is given by increase of weight in the potash-bulbs, and that of the oxygen by increase of weight in the tube filled with caustic baryta, after multiplica-

tion by eight and division by nine to reduce water to oxygen; for water contains eight-ninths of its weight of oxygen.

After ascertaining the normal amount of carbonic acid exhaled, and of oxygen absorbed, by an animal in a given time, it was removed from the box, anæsthetised, again placed in the box, and the gases of respiration estimated. Without giving detailed results, it may be stated that the *effect of anæsthesia with chloroform is to increase the amount of carbonic acid exhaled within a given time.*

3. *Effects on Nervous Phenomena.*—Several curious facts have been elicited with regard to the effects of small doses of chloroform and ether on the rapidity of nervous and mental processes. By a refined method of experimenting with Regnault's chronograph, it was ascertained that a few respirations of air containing chloroform or ether produced remarkable retardation in the time of signalling back that a visual impression had been perceived, although the person operated on was quite unconscious of any such delay. These experiments are interesting chiefly from a psychological point of view.

NOTE ON THE PRESERVATION OF ENCEPHALA BY THE ZINC CHLORIDE. By Professor Rolleston, F.R.S.

It has long been known that Zinc Chloride may be used in conjunction with spirit for the preservation of Encephala. Gratiolet in a note at p. 11 of his famous "Mémoire sur les plis cérébraux de l'Homme et des Primatès," 1854, informs us that a certain Parisian modeller, by name Stahl, was in the habit of hardening brains for modelling, by placing them whilst fresh, and with the membranes adherent, for two or three days in a solution of Zinc Chloride marking 25° on the arèometer of Gay-Lussac. Gratiolet, however, does not say that he himself treated brains in this fashion for his own purpose; if he had so treated them he would have discovered that for purposes of manipulation it is necessary to subject the brain thus acted upon to an immersion in alcohol. This Professor von Bischoff of Munich pointed out in his Memoir on "Die Grosshirnwindungen des Menschen, *Abhandlungen der k. bayer. Akad. der. Wiss.* ii. Cl. x. Bd. ii. Abtheil. 1868, p. 401, or S. A. p. 11, 12," stating at the same time that having employed the solution of Zinc Chloride for 24 years for the preservation of subjects for dissection he had observed that the brains of subjects thus injected, and brains simply put into this solution, presented the following advantages for purposes of study. They become more plastic and tough, less liable to chapping and breaking away in flakes, than brains simply treated with alcohol; but they do require some subsequent supplementary immersion in alcohol of moderate strength to prevent the acid chloride which at first coagulates from softening the albuminous substances of the organ. A second, and this not an inconsiderable advantage, is attained by their allowing the pia mater to be stripped away with much greater ease and rapidity than is the case in brains not thus treated. Especially is this the case in the brains of fœtuses in which, whilst the substance of the convolutions is softer, the amount of their vascular supply is relatively much greater than in adults.

I have little to add to these recommendations except in the way of confirmation based upon the results attained by applying this method to specimens to be preserved permanently in catalogued series. And I may say that a permanent specimen of a brain of any vertebrate animal which has been treated with Zinc Chloride, either injected by the umbilical vessels, as is to be done in the cases of fœtuses, or otherwise brought into relation with it, contrasts very usually with a brain which has been treated with alcohol alone, in having a much smoother and less grumous surface than brains treated in this latter fashion, however painstakingly their membranes may have been picked away from them. The difference may be illustrated by saying, that the surfaces of two sets of brains, thus severally treated, differ very much in the same way that the surfaces of the bones of wild and domesticated representatives of the same species differ.

But, secondly, I would say that the condition of freshness is by no means absolutely necessary for the purposes of making anatomical preparations of brains as M. Stahl appears to have found it to be for the purpose of modelling. Having to deal with the brain of a large Toper shark, *Galeus canis*, some way removed from that condition of freshness which would have rendered it safe to attempt to remove it from the skull, I treated it for some days *in situ*, firstly, with zinc chloride, and subsequently with spirit. After this, it bore removal from the skull as well as the brains of its congeners which came into our hands in more favourable conditions, and in this matter of smoothness and clearness, and what the Germans call the "Glanz" of its surface, it compares to considerable advantage with them (See Prop. 896, *b. e.* Anatomical Department, Oxford University Museum). For the successful application, however, of Broca's method of hardening and shrinking a brain by nitric acid, for which see *Mem. Soc. Anthrop.*, Paris, ii. 1865, p. 84, into a mass which, when dried and varnished, bears handling for an indefinite period; I take this opportunity of saying that I incline to think the condition of freshness is usually necessary. Brains, however, like other organs, vary very much in their consistence and power of taking on consistence after death, and the amount of uncertainty which attaches to this latter mode of preserving brains may perhaps be explained otherwise. Thirdly, I have observed in adult human brains, treated with Burnett's solution of zinc chloride, that the larger arteries will, if not removed sufficiently early, recoil or retract themselves as arteries in a living body will do when cut away from their peripheral ramifications, and so come to imbed themselves in the substance of the convolutions, and thereby channel and disfigure them. In this matter of the expediency of not delaying the removal of the membranes, the nitric acid method coincides with the zinc chloride. (For this, as regards the former method, see Dr Bevan Lewis, cit. Dr J. Crichton Browne, on General Paralysis of the Insane, *West Riding Lunatic Asylum Medical Reports*, vol. vi. 1876, p. 203.)

In conclusion, I may draw attention to the fact that Duvernoy in his Memoir on the Nervous System of the Lamellibranchiata published with exquisite and accurate illustrations in the *Mémoires de l'Institut*, 1854, p. 8, tells us that he used zinc chloride for his dissections.

The specific gravity of Burnett's solution of zinc chloride is about 1·343, and may be used undiluted for the purposes in question. The above method of preserving the brain, which we have for some years carried out in the Oxford Museum, agrees in its essential features with the first stage of the process recently described by Dr Carlo Giacomini in a communication made to the Royal Academy of Medicine of Turin. (See Abstract in Report on recent memoirs on the Anatomy of the Brain in this number of the *Journal*.)

UEBER DIE NACH NEKROSE AN DER DIAPHYSE DER LANGEN EXTREMITÄTENKNOCHEN AUFTRETENDEN STÖRUNGEN IN LÄNGENWACHSTUM DERSELBEN. Von Dr H. HELFERICH in Leipzig. *Deutsche Zeitschrift für Chirurgie, Band X.*

IN this paper Dr Helferich gives the careful measurements of the affected region in 141 instances in which necrosis had attacked some part of one of the long bones. Of these 66 were in the tibia, 45 in the femur, 20 in the humerus, 4 in the fibula, 6 in the radius. In the case of the tibia 29 were at the upper end, 18 at the lower, and 19 in the middle; in the femur, 40 were at the lower end, 3 at the upper end, and 2 in the shaft; in the humerus, 16 were at the upper end, 3 at the lower, and 1 in the middle; in the fibula, 2 were at the lower end, 1 at the upper, and 1 in the middle; in the radius, all 6 were at the lower end. He thus shows that the relation between liability to disease and the rate of growth in a bone and also in the upper or lower end of a bone, which has been remarked by other observers, holds good on the whole. The chief exception is the tibia, which is more liable to necrosis than the femur, though its rate of growth is less. This is explained by the greater liability of the tibia to injury, which also causes its shaft to be more frequently affected than that of other bones. With this exception necrosis is most frequent near the ends of the diaphyses, and in each case near that end at which the growth is the greater. With reference to the relative rate of growth at the two ends of a long bone, he cites the observations of Duhamel, *Mém de l'Acad. Roy. d. Sciences*, 1843; Flourens in Malgaigne's *Traité d. Anat. Ch.*; and Humphry, *Med.-Ch. Trans.* xliv.

The numerous careful measurements which the author has made show that interference with the growth of the part affected is frequent; and he suggests that it is often overlooked in consequence of its being, in some instances, slight, and in others marked by a compensatory greater natural growth in the bone or bones of another segment of the limb. In the femur he found 13 instances of shortening to 3 of lengthening; in the tibia, 12 of shortening to 14 of lengthening; in the humerus, 4 of shortening to 1 of lengthening; in the radius, 2 of shortening. These interferences with the length do not take place after the growth of the bone has ceased and after the epiphyses are ankylosed to the shafts. They depend upon some influences exerted on the epiphysial cartilages by the disease. The lengthening is due to the prolonged hyperæmia attendant upon necrosis extending to the epiphysial cartilage, and giving an impetus to the cell formation there; and it is most frequent in the tibia, because the necrosis in that bone frequently affects the shaft; whereas in other bones the disease, in consequence of its being nearer to epiphysial cartilage, is more likely to cause destruction of the cartilage and consequent arrest of growth.

Examples are quoted in which disease of the epiphyses occurring in affections of joints was attended with elongation of the bones; but that is rare in comparison with shortening from this cause. He alludes to the possibility of necrosis causing impairment or destruction of the nearest epiphysial cartilage, and arrest of growth at that, the proximal, end, and merely inducing hyperæmia and increase of growth at the other and more distant end. Thus there would be diminution and increase of growth in the same bone, and produced by the same disease affecting the two ends in an unequal degree.

The lengthening of the adjacent bones, which, though rare, may be associated either with lengthening or with shortening of the diseased bone, is in either case to be attributed to the accession of blood supply to the limb, which is in some way brought about by the disease. A more precise explanation of it than this is not easy to give, and experiments upon animals with reference to it which have been made fail to throw much light upon it. Like the similar change in the diseased bone, it must be limited to the growing period of life.

The associated shortening of the adjacent bones may be attributed, as indeed may sometimes in part be that of the diseased bone, to inactivity of the limb. It is most frequently observed when the disease is in the proximity of a joint, the use of the limb being in such cases most interfered with.

The associated elongation of the fellow-bone, as in the case of the fibula when the tibia is elongated, may depend upon the accession of blood extending to the fibula, or upon tension exerted upon it by the growing tibia, or by both these causes. The resistance of the fibula may, however, limit the elongation of the tibia, or may cause it to assume a curve, as has been observed by Stanley and Paget. In some instances, however, the fibula has not been thus elongated, but has undergone luxation from the upper part of the tibia, its lower end remaining fixed to the tibia and the upper end being drawn away from it. Two cases of shortening of the tibia were observed by Humphry, in one of which the upper end of the fibula was luxated and projected above its articular surface in the tibia, and in the other the lower end projected downwards and touched the ground. Other deformities resulting from the unequal length of the two bones of one segment of a limb are mentioned.

REPORT ON PHYSIOLOGICAL CHEMISTRY.[1]

By J. Graham Brown, M.D.

Sect. I. On Albumins, Glycogen, Blood, and Fermentation.

Weyl—On Animal and Vegetable Albumins.

Zeitschr. für Physiol. Chemie, i. p. 72.

In this communication the author treats of the various globulins which he defines, along with Hoppe-Seyler, as albuminous bodies which are precipitated from their neutral solutions by the addition of a large excess of water, and which are completely soluble in dilute solutions of neutral salts of the alkalis. After long contact with water they gradually become insoluble in solutions of chloride of sodium of any concentration, and pass first into the condition of albuminates, and later into that of coagulated albumins. Acids and alkalis change them, slowly or quickly, according to the concentration and the duration of the process, into substances which are indistinguishable in their reactions from those produced by the action of water.

The animal globulins divide themselves into two groups, according to their solubility in solutions of chloride of sodium. To the first series belongs *Vitellin*, which is soluble in salt solutions of whatever concentration, and in the second group are *Myosin*, *Fibrinogenic substance*, and *Serum-globulin*, which are only soluble in solutions of salt of a fixed concentration, being precipitated from their neutral solution by the addition of solid chloride of sodium.

1. Vitellin from the yolk of egg coagulates in a 10 per cent. salt solution at 75° C.

2. Myosin from the muscle of the horse coagulates in the same solution at 55°–60° (Kühne).

3. Serum-globulin, the only globulin which is contained in blood-serum, is to a large extent, but not completely, precipitated from its neutral solution in chloride of sodium by saturation of the solution with that salt. This substance coagulates at 75° C. Since Paraglobulin only differs from Kühne's globulin in its being mixed with fibrin ferment, and since, further, there exists no as yet recognisable difference between globulin (Kühne) and serum casein (Kühne), it follows that there exists in blood-serum but one globulin. This body can be prepared by diluting blood-serum with 15 volumes of water, passing through it carbonic acid gas, and adding a few drops of dilute acetic acid. This substance Weyl has named *serum globulin*.

4. The *vegetable globulins* shew the general reactions of animal globulins, and of the animal albumins generally.

[1] This report, which contains references to only a few of the more important of the memoirs on Physiological Chemistry, is confined, with but few exceptions, to the literature of 1877.

5. *Vegetable vitellin* can be obtained from oats, maize, peas, sweet almonds, &c., but in the present instance the author made use of the para-nut (Brazil nut, the *seeds* of the *Bertholletia excelsa*, not the *fruit* as Weyl has it) for its preparation. (The details of the process are accurately given in a subsequent communication by Schimiedeberg, a short abstract of which will be found further on in this report). The vegetable vitellin, so obtained, corresponds in all its reactions with vitellin from the yolk of egg. It coagulates at 75° in 10 per cent. salt solution.

6. These crystals from the para-nut are at first membraneless, but subsequently a membrane forms on them by precipitation (the haptogenic membrane of Ascherson).

7. By treating powder of peas, oats, sweet almonds, &c. with 10 per cent. salt solution, Weyl obtained, in addition to vitellin, another substance which he names *vegetable myosin*. It corresponds in all its reactions to the myosin found in striped muscles, and coagulates in a 10 per cent. salt solution at 55°–60° C.

8. In no fresh vegetable seed is there ever an albuminate present. All such substances hitherto found are artificial products, or result from secondary processes in the seeds which have nothing to do with the natural development of the plant.

9. All animal and vegetable globulins, when brought in contact with water, with acids, or with alkalies, apparently pass first into albuminates, and later into the condition of coagulated albumin.

SCHMIEDEBERG—ON THE PREPARATION OF PARA-NUT CRYSTALS. *Zeitschr. f. phys. Chemie*, i. S. 205.

The vitellin which has been shown by Weyl to exist in the Para-nut, can be obtained in a crystalline form in combination with magnesium in the following manner:—The nuts are powdered in an ordinary coffee-mill, and then rubbed up with repeated small quantities of a mixture of oil and petroleum, and pressed through a linen cloth, through the meshes of which the protein grains readily pass. Subsequent washing with pure petroleum ether removes all trace of oil, and the dried precipitate is treated with a large quantity of distilled water, and kept at a temperature of 30°–35° C. When carbonic acid gas is passed through this solution, a precipitate is formed which has all the characters of vitellin. This precipitate, when still moist, is treated with burnt magnesia and with water of the above temperature. The magnesium salt of vitellin forms, and is dissolved. When the solution becomes cold and sufficiently concentrated, this salt separates out in a crystalline form. The crystals so obtained are well formed, glistening, and of the size of poppy-seeds.

This is the first albuminous salt which has ever been obtained in a crystalline condition. The vitellin in it plays the part of an acid, but of a very weak one, as it is unable to decompose carbonate of lime.

SCHÜTZENBERGER—THE PRODUCTS OF DECOMPOSITION OF ALBUMEN WITH BARIUM HYDRATE. *Ber. d. deutsch. Chem. Ges.* x.; *Virch. and Hirsch's Jahresber.* 1877. i. p. 124.

In addition to the usual decomposition products, S. finds Tyroleucin to be present, having the formula $C_7H_{11}NO_2$. It is tolerably soluble in water, very slightly in alcohol. Heated without contact with air, it breaks up, giving off water and carbonic acid, and forming three nitrogenous bodies, C_7H_9NO, $C_7H_{11}NO_2$(amidovalerianic acid), and $C_8H_{11}N$. The last of these has the properties of a base, and corresponds in its composition to Collidin.

MALY—ON THE FORMATION OF ACID IN THE ORGANISM, AND ON SOME PROPERTIES OF BLOOD-SERUM. *Zeitschr. für phys. Chemie,* i. p. 174.

In order to understand why it is that from an alkaline blood acid urine is formed, Maly points out that several facts must be taken into account.

1. In spite of its alkalinity, blood-serum contains salts which have an acid reaction (acid phosphate of sodium).

5. The salts contained in the blood which have an alkaline reaction (double phosphate of sodium, and bicarbonate of sodium) are theoretically acid bodies.

3. During the process of oxidation, acids are constantly being added to the blood; chiefly carbonic acid, then the intermediate organic acids, lastly, phosphoric and sulphuric acids.

4. The divisions and combinations of acids and bases in the blood is in the highest degree complicated. A great variety of neutral salts and (on account of the presence of free carbonic acid) a great variety of acid salts must be present together in the serum. Alkaline substances exist there only in an empirical sense; of *theoretically* alkaline bodies there are none present.

5. As has been pointed out by many authors (first by Graham), acids and acid substances dialyse more rapidly than neutral bodies. Such a filtering apparatus as is provided in the kidneys, or in the sweat-glands, may well be able to bring about dialytic changes in such a fluid as blood, from which we, with our coarse and imperfect dialysers, can extract no more acid.

BÖHM AND HOFFMANN—ON THE INJECTION OF GLYCOGEN INTO THE CIRCULATION. *Arch. f. exp. Path.* &c. vii. S. 489. *Centralbl. f. die Med. Wiss.* 1878, p. 126.

The injection of 3–10 grammes of glycogen, in the course of a few hours, into the jugular vein of a cat, causes hæmoglobin to appear in the urine. Glycogen, then, belongs to the substances which cause solution of the blood corpuscles.

The urine, after separation of its albumin, rotates polarised light, and reduces oxide of copper; but the reduction is five to ten times

less in amount than would correspond to the rotation. By precipitation with six to eight times its volume of 95 per cent. alcohol, it is possible to isolate its rotating substance. This substance dissolves in water without any opalescence, it is not coloured by iodine, nor does it reduce Fehling's solution; but, on the contrary, prolonged boiling with acids converts it completely into grape-sugar.

This substance, then, which appears in the urine after the intravenous injection of glycogen, is not unchanged glycogen, but is achroodextrin (Brücke).

ABELES—ON GLYCOGEN. *Wiener Med. Juhrb.* 1877. *Centralbl. für die Med. Wiss.* 1877, S. 268.

1. *On the Preparation of Glycogen by means of Chloride of Zinc.*—The accurate estimation of the quantity of glycogen in the muscles is only to be obtained by boiling them with caustic potash. To employ this method, however, involves the use of a large quantity of a solution of iodide of mercury in iodide of potassium. Instead of making use of this solution, Abeles precipitates the albuminous substances by means of chloride of zinc. The muscles are boiled down in water containing caustic potash, and the fluid so obtained treated with hydrochloric acid, to diminish the excessive alkalinity, but so as to leave it still with an alkaline reaction. It is then again boiled for 20–40 minutes after the addition of chloride of zinc, whereby the albumin separates out in thick masses, and is readily removed by filtration. The glycogen which is precipitated by means of alcohol from this solution must be ashed, and the ash deducted. No formation of sugar from glycogen takes place by boiling along with chloride of zinc.

2. *The behaviour of Muscle-Glycogen under the action of Curara.*—In a dog which had fasted for five days, the quantity of sugar in the blood was 0·046 per cent.; one hour after the administration of curara (artificial respiration) it had reached 0·13 per cent., an increase which Abeles held could not be accounted for by the using up of the small quantity of glycogen still contained in the liver after a five days' fast. He therefore determined to estimate the amount of glycogen contained in the muscles before and after the administration of curara. For this purpose in narcotised animals the muscles of one thigh were removed, the wound closed, curara injected, and later, the muscles of the other thigh excised. The influence of curara lasted in different experiments from 25 minutes to 1¾ hours. In all cases the quantity of glycogen in the curarised muscles was somewhat in excess of that in the non-curarised.

3. *The Combination of Glycogen with Baryta.*—If one adds to a solution of glycogen a saturated solution of caustic baryta, a voluminous precipitate forms, which, after long standing, separates tolerably completely. This precipitate collected, and dried *in vacuo* at 100° C., gives the composition $C_{18}H_{30}O_{16}Ba$. This precipitate can be formed direct by the addition of baryta water to decoction of liver, and glycogen can be set free from it by the addition of dilute sulphuric

acid; but this method is not of much practical value, since it is very difficult to separate the sulphate of barium from the glycogen solution.

M. TRAUBE—ON THE CONDITION OF THE YEAST PLANT IN A MEDIUM FREE FROM OXYGEN. *Ber. d. deutsch. chem. Ges.* x. p. 510.

Confirms Pasteur's observation that there are organisms which can exist without free oxygen. But in mineral cultivating solutions which contain, in addition to various salts of potassium and magnesium, only sugar, and no free oxygen, the yeast plant cannot live. This goes against Pasteur's theory that, when the air is excluded, the *torulæ* form the oxygen necessary for their existence from the sugar.

KÜHNE—*Unters. aus d. phys. Institute zu Heidelberg*, Bd. i. *Jahresb. von Virch. and Hirsch*, 1877, i. p. 130.

Denies the identity of trypsin (pancreas ferment), and the ferment associated with bacteria. By the action of trypsin on albumin, indol is never produced. This substance is only formed by the action of bacteria which have found their way into the digesting fluid. The formation of indol can be prevented by the addition of various antiseptics, and also, if the dried powder of the pancreas itself be used, digestion may go on for months without there being produced any smell of putrefaction, or any formation of indol.

Kühne points out a further distinction between the two varieties of ferments, viz., that when peptone is treated with trypsin a part is always left unaltered (antipeptone). If this residue is treated with new quantities of trypsin, no more leucin and tyrosin are formed. If the solution be now inoculated with bacteria, tyrosin is at once produced along with the smell of indol. The action of trypsin on gelatin produces neither glycocol nor leucin, but bacteria form both.

In order to show that the large quantites of leucin and tyrosin which former authors have extracted from the pancreas do not exist there in the natural condition, but are the products of self-digestion, Kühne extracted the fresh gland with boiling water, and digested it with gastric juice. After the process was ended, no tyrosin was discoverable, and very little leucin.

BUCHHOLTZ—ON CONDITIONS OF NUTRITION OF BACTERIA. *Arch. f. exp. Path*, &c. vi. S. 81. *Jahresb. von Virchow and Hirsch*, 1877, i. p. 131.

1. Bacteria do not require albumin for their nourishment, they thrive if they are supplied with nitrogen in the form of ammonia salts, carbon in the form of sugar, tartaric acid, or citric acid.

2. The presence of such salts as phosphate of potash, phosphate of lime, sulphate of magnesia, though not essential, is of service.

3. Tartaric acid can only be replaced by citric acid. Oxalic, lactic, acetic, and butyric acids are not suitable.

4. Urea and glycerin cannot replace tartaric acid.

5. If the nutritive fluid contains sugar, the bacteria form from it carbonic acid, formic acid, acetic acid, butyric acid, succinic acid and glycerin. If only citric or tartaric acids are present, then formic, acetic, and butyric acids are produced.

BERT—ON THE EMPLOYMENT OF OXYGEN AT A HIGH TENSION FOR PHYSIOLOGICAL INVESTIGATION—POISONS AND VIRUS. *Comptes rendus*, t. lxxviii. p, 1130.

The author had already observed some years ago that oxygen at high tension rapidly determined death in all living beings, or rather, to put it exactly, all anatomical elements, whether they be isolated (as is the case with blood corpuscles and microscopical organisms) or grouped in the tissues of complex organs. In regard specially to the process of *fermentation*, he states that he has demonstrated that all processes of this variety which are dependent on the presence of living organisms (putrefaction, acetous and venous fermentation) are definitely arrested by the action (even transitory) of compressed oxygen, whilst those which are the result of a dissolved matter resist perfectly this influence.

Bert continues these observations in the present communication. The poison of scorpions, subjected to compressed oxygen, resists perfectly, and is thus comparable to the vegetable alkaloids. Vaccine lymph submitted for more than a week to the action of oxygen at 50 atmospheres pressure, retains its properties, and the same is true as regards the virus of glanders. The symptoms which follow the inoculation of these fluids are not then due (in Bert's opinion) to the presence of minute organisms, but result from some independent and unorganised ferment. This ferment, however, may be attracted to and attached to these organisms just as hæmoglobin is to blood corpuscles.

SCHLŒSING AND MÜNTZ—ON NITRIFICATION BY MEANS OF ORGANISED FERMENT. *Comptes rendus*, t. lxxxiv. and lxxxv.

It is generally admitted that the nitrates engendered in the soil are the result of the combustion of ammonia and of azotised matters of organic origin, but it has not been settled whether this process results from a purely chemical action or is produced by minute organisms acting as ferments.

To elucidate this point a large glass tube, one metre long, was filled with a mixture of 5 kilogrammes of superheated sand and 100 grammes of carbonate of lime. Each day a small quantity of sewage water was poured on it, and it was so arranged that the liquid took eight days to percolate through. For the first five days after the liquid appeared at the lower end of the tube it contained ammonia, the quantity of which remained constant. Then appeared nitrate of potassium, and this salt increased rapidly in amount, so much so that in a short time no more ammonia could be detected. After the experiment had lasted for four months, a small glass containing chloroform was placed on the surface of the sand, and its vapour was diffused through

the tube by means of a strong current of air. As the fluid took eight days to percolate, it was not to be expected that the nitrates would disappear before that time, but after ten days all trace of nitrate had disappeared, and ammonia was found to its original amount. For many weeks no formation of nitrates took place. It was at once restored exactly eight days after the water poured on the surface had been mixed with some soil which the authors knew to be favourable to nitrification.

In a second communication these authors confirm by other similar experiments the results of the one just detailed. They conclude that the process of nitrification results from the action of an organised ferment, and they hope to be able to isolate the organisms.

[This result has been confirmed by Warrington, *Ber. d. Deutsch Chem. Ges.* x.]

HOPPE-SEYLER—ON THE PROPERTIES OF BLOOD-PIGMENT. *Zeitschr. f. Phys. Chemie*, i. p. 121.

1. *Hæmoglobin as a test for Free Oxygen.*—It is well known that solutions of hæmoglobin, if they contain only a trace of oxy-hæmoglobin, show the two absorption lines which are characteristic of that substance. The author placed solutions of hæmoglobin in contact with hydrogen gas, containing traces of oxygen, in order to determine to what degree of delicacy this test extended. It was found possible to recognise the presence of oxygen when, at the ordinary temperature, the tension of the gas corresponded to 1·5 mm. mercury, or when at the ordinary atmospheric pressure the gaseous mixture contained 0·191 volume per cent. of oxygen. Since 1 c.c. of gaseous mixture suffices, it may be concluded that ·002 c.c. of oxygen in the gaseous condition can be detected by this test.

2. *The Power which Hæmoglobin possesses to resist the Action of the Putrefactive Process and the Ferment of Pancreatic Juice.*—Solutions of oxy-hæmoglobin in closed tubes do not change their composition even after being kept for months or years, thus differing from albumins, which break up, as the author has shown, into CO_2, NH_3, leucin and tyrosin. In the same way solutions of hæmoglobin are not affected by the pancreas-ferment.

3. *The Persistence of Carbonic Oxide Hæmoglobin in the presence of Putrefaction and Pancreas Ferment.*—This variety of hæmoglobin can be preserved in closed tubes, and under these circumstances retains the two absorption bands which are characteristic of its presence. In this way blood obtained from a case of carbonic oxide poisoning can be preserved for future demonstration.

4. *On the Action of Putrefaction and Pancreatic Ferment on Oxy-Hæmoglobin.*—So long as air or oxygen is excluded no change takes place, but whenever oxygen enters decomposition ensues with the formation of meta-hæmoglobin.

5. *On the Detection of Oxygen absorbed in the Secretions by means of Hæmoglobin.*—Solutions of hæmoglobin, when brought into contact with animal secretions, and at the same time protected from the sur-

rounding air, indicate, by the formation of the two spectral bands, the presence of oxygen in these secretions, if the gas is dissolved in them. The secretions of the parotid and of the submaxillary glands contained much oxygen, but the urine and bile are free from any trace. [As Pflüger has already shown, *Arch. f. die Ges. Phys.* i. S. 686, ii. S. 156.]

GUTTMANN—ON THE INJECTION OF DILUTE ACIDS INTO THE BLOOD. *Virchow's Arch.* lxix. p. 534.

He confirms the results obtained by Aré (*Comptes rendus*, t. lxxxi.), viz., that dilute acids, when thrown into the blood stream do not determine coagulation. The injections were made into the jugular vein of rabbits, and the length of time occupied in each operation varied from three-quarters to four minutes, according to the quantity of fluid injected (6–40 c.c.).

The symptoms which follow the injection consist of a more or less marked dyspnœa which comes on immediately. This, Guttmann holds to be due to a temporary paralysing action of the acids on the heart, indicated by a weaking of the apex-heat. If the quantity of acid be too great, this paralytic condition is fatal, and the animal dies with symptoms of great dyspnœa, convulsions, and expophthalmos. After death the right ventricle is found distended with the blood. The blood corpuscles show no microscopic change.

DROSDOFF—ON THE ANALYSIS OF THE BLOOD OF THE PORTAL AND HEPATIC VEINS. *Zeitschr. für phys. Chemie.* i. p. 232.

The dogs which were used in these experiments were fed with bread, meat, and milk three to four hours before the blood was taken. The blood both from the hepatic and the portal vein was taken during life, the former by means of a long narrow catheter passed through the jugular vein and vena cava inferior to the opening of the hepatic vein, the latter by means of a steel canula thrust into the portal vein. As the result of four experiments it was shown—

(1) That the blood of the portal vein contained more fixed matter than that of the hepatic.

(2) The blood of the hepatic vein contained a larger amount of cholesterine than that of the portal vein.

(3) The same was true of lecethin.

(4) On the contrary, the hepatic vein contained more fat than the *vena portæ*.

(5) The portal blood is richer in phosphate of soda than that of the hepatic vein.

FREDERICQ—THE DISTRIBUTION OF THE CARBONIC ACID OF THE BLOOD BETWEEN THE CORPUSCLES AND THE SERUM. *Comptes rendus*, t. lxxxiv., p. 661.

The assertion that all, or almost all, the CO_2 in the blood is contained in the serum, although very generally accepted, does not rest on

any satisfactory basis of proof, nor does it accord with some analyses of Schmidt, Preyer, and Setchenow. This idea the author shows to be incorrect, and gives various results of the analysis of horse blood in proof. The red blood corpuscles contain about half as much carbonic acid as does an equal volume of serum.

SECT. II. DIGESTION.

RICHET—OBSERVATIONS ON A CASE OF GASTRIC FISTULA. *Comptes rendus*, t. lxxxiv. p. 450 and p. 1517.

The case on which these observations were made was that of a young man on whom gastrotomy had been performed on account of obstruction of the œsophagus. The observations are all the more valuable, seeing that the œsophageal obstruction was so absolute that no saliva became mixed with the gastric contents. He draws the following conclusions from his first series of observations:—(*a*) The medium acidity of the gastric juice (whether pure or mixed with food) was equivalent to 1·7 grammes of hydrochloric acid in 1000 grammes of liquid. It was never lower than 0·5 gramme nor higher than 3·2 gramme. (*b*) The quantity of liquid contained in the stomach had no influence on the acidity. (*c*) Wine and alcohol augment the acidity of the stomach; cane-sugar diminishes it. (*d*) If a quantity of acid or alkaline fluid be thrown into the stomach, the normal acidity becomes rapidly re-established—in the course of an hour or two. (*e*) The gastric juice is more acid during digestion than in the intervals. (*f*) It becomes still more acid towards the end of digestion. (*g*) The sensations of hunger and thirst are not dependent on the amount of acidity, nor on the state of emptiness of the stomach.

The gastric juice derives this acidity chiefly from mineral acids; but when food is mixed with it, lactic acid also appears.

AFANASSIEW AND PAWLOW—ON THE SECRETION OF THE PANCREAS. *Pflüger's Arch.* xvi.; *Virch. and Hirsch's Jahresbericht*, i. p. 154.

The pancreatic secretion in dogs from permanent fistulæ is diminished, or completely arrested, by the action of atropine (0·005 – 0·01 c.c. of a 1 per cent. solution). The same result was also produced by strong sensory irritation. It was observed that in animals which were tied down, and had the trachea opened, no secretion flowed. If any secretion took place in curarised animals, it at once stopped when a sensory nerve (the crural or the sciatic) was laid bare.

SALKOWSKI—ON THE ACTION OF HEAT ON PANCREAS FERMENT. *Virchow's Archiv*, lxx. S. 158.

The author has convinced himself that there is no difference between the action of pancreas ferment in its natural state and after it has been heated to 160° C. Both produce pepton, leucin, and tyrosin in the same time, and apparently in the same way, when acting on fibrin.

From small pieces of fibrin he obtained, after five to six hours digestion, the like quantity of leucin and tyrosin in the most beautiful crystals, whether the pancreatic ferment had been previously heated or not. One cannot therefore imagine that organisms help in producing this digestive action. If the ferment has been superheated, the fibrin preserved for a long time previous in glycerine, and finally the vessel cleaned, superheated, and its mouth closed with cotton wool; if, in short, all the precautions are taken which are necessary in investigating the phenomena of putrefaction, no organisms will appear during the time required for pancreatic digestion.

SCHÜLEIN—ON THE ACTION OF THE SALTS OF THE BILE ON THE INTESTINAL CANAL OF DOGS. *Zeitschr. f. Biol.* xiii.; *Hofmann and Schwalbe's Jahresb.* vi. p. 212.

Bile and its acids, when brought into the intestine of dogs, cause diarrhœa by increase of peristaltic action, and in large doses also vomiting. The action of cholalic acid is more powerful than either the compound acids (taurocholic and glycocholic acids) or bile itself. The necessary dose of cholate of sodium to cause diarrhœa in a dog is from 0·5 to 1·0 gramme. Schülein concludes that normally the peristaltic action is increased by the presence of bile.

A. BOKAY—ON THE DIGESTIBILITY OF NUCLEIN AND LECETHIN. (From Hoppe-Seyler's Laboratory in Strasbourg). *Zeitschr. f. Phys. Chemie*, Bd. i. S. 157.

The author sums up the results of various experiments on dogs, on the above subject, as follows:—

1. Nuclein is attacked by none of the digestive ferments, and it is probably to be considered as a constant component of the fæces, since most foods contain it.

2. Lecethin is broken up by the pancreatic ferment into glycerin-phosphoric acid, neurin, and fatty acids. These decomposition products are at least in part absorbed through the intestinal canal (probably in the form of salts), since, after diet which is rich in lecethin, the phosphoric acid elimination in the urine was increased, while in the fæces not the slightest traces of lecethin or of glycero-phosphoric acid could be found.

W. DROSDOFF—ON THE ABSORPTION OF PEPTONES, OF CANE SUGAR, AND OF SULPH-INDIGOTIC ACID FROM THE INTESTINE, AND THEIR DETECTION IN THE BLOOD OF THE PORTAL VEIN. (From Hoppe-Seyler's Laboratory in Strasbourg). *Zeitschr. f. Phys. Chemie*, Bd. i.

The author gives the results of a series of experiments performed upon dogs, in which he drew off from the portal vein sufficient blood for the necessary analyses, three or four hours after the animals had received a meal consisting of boiled meat and milk, to which, in some cases, cane sugar was added, and in others, indigo-carmine. He comes

to the following conclusions:—During digestion unaltered peptone can be recognised in the blood of the portal vein, although often only in traces. Immediately after its withdrawal from the portal vein, the blood contains more peptone than when it has stood for a little time; the peptone then appears to undergo a chemical change in the blood.

The greatest part of the cane sugar is absorbed unchanged into the blood of the portal vein, since it is found there in considerable quantity. The cane sugar in this fluid becomes gradually converted by the action of a ferment into grape sugar, and this may also disappear from the same cause. But it is impossible to lay down any rule regarding the rapidity of the change.

Indigo-carmine is absorbed into the blood of the portal vein. The quantity of this substance in the blood of the portal vein at any given time is naturally much smaller than in the intestine, but, and this is certainly of interest, it is also much smaller than in the urine. Indigo-carmine probably passes outwards from the intestinal canal into all the tissues, but, since these have an alkaline reaction, it is not deposited there.

SECT. III. URINE.

QUINCKE—ON THE INFLUENCE OF CARBONIC ACID DRINKS ON THE URINARY SECRETION. *Arch. f. exp. Path.* vii.; *Jahresb. von Virchow and Hirsch*, 1877, i. p. 159.

Observations were made on several individuals, to whom were administered large quantities of water containing carbonic acid, and who on other days drank ordinary water. The urines passed in the three hours which followed the draughts were compared in each instance, and it was found that that which succeeded the draught of effervescing water was always greater in amount than the urine which followed the imbibition of ordinary water. Quincke holds that this result cannot proceed from the carbonic acid as such, but is rather the effect of the increased rapidity of the absorption of water in the stomach and intestines. The effect is not observed if an effervescing powder dissolved in little water be swallowed. The well-known rapid effect of effervescing wines he also refers to the increased rapidity of absorption produced by the carbonic acid they contain. In experiments on dogs the drinking of carbonic acid waters caused no change in blood pressure, and influenced the pulse frequency only very slightly. The respirations were deep and slow.

SALKOWSKI—ON THE FORMATION OF UREA IN THE ANIMAL BODY, AND THE INFLUENCE OF SALTS OF AMMONIA ON THE SAME. *Zeitschr. f. Phys. Chemie*, i. p. 1.

The author lays great weight on the relation between urea and the amount of sulphates in the urine. If one finds, after introduction into the body of a nitrogenous compound, an increase of the urea excreted without any corresponding increase of sulphates, it may be concluded that the additional amount of urea is really owing to the nitrogenous

substance administered, and not merely the result of an increased breaking up of albumin.

The results of the administration of chloride of ammonium in rabbits are as follows:—

1. A very slight and unimportant increase in the ammonia salts excreted by the kidney.

2. The results of Bunsen's method of urea determination, and Seegen's for the estimation of the total amount of nitrogen eliminated, come very close together, showing that urea is the only nitrogenous body which is present to any amount in the urine.

3. The urea increases markedly on the days on which chloride of ammonium is given. The increase not only corresponds to the amount of nitrogen which the chloride of ammonium contains, but is somewhat more, since the breaking up of albumin in the body is somewhat increased by the administration of that salt.

4. The excretion of sulphates does not correspond to the urea elimination. But if the amount of urea which corresponds to the quantity of nitrogen in the chloride of ammonium be deducted from the total amount excreted, the remainder bears the same proportion to the sulphates excreted as the total quantity of urea does to the sulphates on days when no chloride of ammonium was administered.

All these results go to show that the nitrogen of the chloride of ammonium in the bodies of rabbits passes over, for the most part, into urea.

SCHIFF—ON A TEST FOR UREA. *Bericht. d. Deutschen Chem. Ges.* x, p. 773.

While most aldehydes enter into combination with urea in watery or alcoholic solution, surfurol acts differently, remaining unchanged. But with nitrate of urea surfurol forms a deep violet colour, which gradually darkens from the formation of a black substance.

This tint is not produced by nitric acid, as none of the mineral acids cause any change of colour if the surfurol be perfectly fresh. But while neither acids nor urea separately produce this effect, when they are added together to a solution of surfurol the change takes place. If one add to a solution of urea three-parts of a saturated solution of surfurol and one or two drops of hydrochloric acid, the fluid gradually becomes coloured a beautiful purple-violet and solidifies into a dark brown mass. This reaction takes place more slowly and to a less marked degree with allantoin, but does not occur in the case of a long series of amides which the author names, among which may be noted taurin, glycochol, creatin, uric acid.

SALKOWSKI AND MONK—ON THE RELATION WHICH THE REACTION OF URINE BEARS TO THE AMOUNT OF SALTS OF AMMONIA WHICH IT CONTAINS. *Virchow's Arch.* lxxi. p. 500.

The experiments were undertaken to ascertain whether if the urine of carnivora (viz., dogs) when rendered alkaline by the administration

of a salt of a vegetable acid (acetate of sodium), would suffer diminution in the quantity of ammonia it contained, and thus approximate to that of the herbivora. This was found to be the case. The estimation of ammonia was carried out by the process of Schlösing, and also by that of Schmiedeberg. The results obtained by the latter method were uniformly 10 per cent. below those of the former.

The results obtained by the administration of acetate of sodium to dogs were:—(1.) Diuresis to such an extent that under favourable conditions the quantity of urine doubled itself. (2.) An increase of the total nitrogenous elimination (average from 3 to 5½ per cent.) (3.) An extraordinary diminution of the ammonia in the urine, which, so long as the urine was alkaline, was only equal to a fourth part of the former quantity.

JAFFE—ON THE EXCRETION OF INDICAN UNDER PHYSIOLOGICAL AND PATHOLOGICAL CONDITIONS. *Virchow's Arch.* Bd. 70. S. 72.

For the exact details of the method he employed for the estimation of indican in the urine the author refers to a former communication on that subject in *Pflüger's Archiv.* for 1870. In brief it was as follows:—

If to 10 c.c. of urine in a test-tube an equal quantity of hydrochloric acid be added, and then very cautiously a drop or two of a strong solution of chloride of lime, there is an immediate separation of indigo if a trace of indican exist in the urine. This blue precipitate may not be immediately apparent, but if the urine be filtered it may be thus obtained in a recognisable condition. On this reaction is founded the process for quantitative analysis. In a measured quantity of urine the indigo is thus separated, collected on a weighed filter, washed with cold and hot water, and finally with hot ammonia, dried, and weighed.

The observations were partly made upon dogs and partly on patients. The author indicates that he has not at his command sufficient data to enable him to point out more than a few leading facts of clinical value.

1. Diseases of whatever variety which prevent the forward movement of the contents of the small intestine produce an appreciable increase in the amount of indican in the urine. Exceptions from this rule may occur in cases where the obstruction is only of very short duration, or where (if such rare cases may exist) there is no nitrogenous substance in the intestine, nor any such substance swallowed during the progress of the disease.

2. In acute diffuse peritonitis the amount of indican in the urine is much increased, probably because here also the peristaltic action of the bowels is much impeded.

3. Obstruction of the large intestine probably also causes an increase of indican in the urine. Jaffe only saw one case of this description, and from unavoidable causes the observation of this patient was incomplete.

In dogs the obstruction of the small intestine by means of a

ligature caused a considerable increase in the quantity of indican in the urine. Ligature of the large intestine caused no such increase.

MUNK—ON THE ESTIMATION OF AMMONIA IN THE URINE. *Virchow's Arch.* lxix. p. 361.

In every fresh urine ammonia is present in the form of one of its salts, in small quantity in the human urine, but in much larger amount in that of dogs. Munk has performed a series of control experiments to ascertain whether the method of Schlösing (recommended by Neubauer) is reliable in the case of urines which contain a large quantity of ammonia. This method consists, shortly, in setting free the ammonia from its combinations by the addition of milk of lime. The fluid so treated is then brought under a bell-glass, under which is placed a measured quantity of acid. In course of time all the ammonia becomes combined with this acid, and is so estimated. Munk controlled the results obtained by this method by making in each case a parallel analysis with chloride of platinum.

He found that after forty-eight hours the results obtained were very nearly the same. But a little more ammonia is obtained on the following days; and if this be added, the result is rather higher.

The milk of lime can very well be replaced by soda solution, but the process is then much slower.

HOFMEISTER—ON LACTOSURIA. *Zeitschr. f. Phys. Chemie*, i. p. 101.

The urine of pregnancy has often been shown to possess many of the properties of diabetic urine, but hitherto much doubt has been expressed as to whether the substance which reduces copper solution is really sugar or not. Leconte (*Compt. rendu.* 44) failed to isolate this questionable sugar, and Heynsius (*Weiner. Med. Woch.* 1858, No. 19) doubted whether it was of a saccharine nature at all, as he found it to be soluble in absolute alcohol. Sinéty established the right-handed rotation of the substance in two cases, and in addition showed that it exhibited the phenomena of fermentation.

The author precipitated repeatedly with acetate of lead and ammonia the urine of a pregnant woman which contained a reducing substance. The precipitates were washed, treated with sulphuretted hydrogen, oxide of silver, &c., and finally an alcoholic solution was obtained which, on slow evaporation, yielded crystals to the amount of 3·4 grammes. This substance, in crystalline form, melting-point, composition, optical properties, power of reduction, increase of optical properties and of power of reduction after boiling with acids, corresponded exactly with milk-sugar.

The retention of milk allows of the absorption of milk-sugar and its excretion by the urine.

RUNEBERG—ON ALBUMINURIA. *Nordiskt medicin. Arkiv.* Bd. ix.

(Founded on Experiments made in the Pathologico-Chemical Laboratory of Prof. Hofmann in Leipzig.)

Albuminous substances do not in reality dissolve in water, but their

so-called solutions are really emulsions of a very fine variety. On filtration they behave exactly like other emulsions, but different albumins show great differences in regard to filtration. The degree of pressure under which one filters an albuminous fluid through an animal membrane does not affect the rapidity of filtration in the manner which, on theoretical grounds, would appear most probable. The more the pressure is raised the less permeable the membrane becomes to albuminous substances (as holds good for all fine emulsions), and the permeability increases in proportion as the pressure is lowered. If the membrane has fluid pressure on both sides, the *difference* between the two pressures has the same influence on the transudation of albumin as if it had been the unopposed pressure on one side alone, *i.e.*, when this difference increases the transudation diminishes, and *vice versâ*, independently of the absolute elevation of pressure on one or the other side.

In the opinion of the author, all the forms of albuminuria which are unassociated with disease of the Malpighian corpuscles are the result of a notable diminution of blood pressure in the glomeruli, or, to speak more correctly, a diminished difference between the pressure in the glomeruli and that in the uriniferous tubules, this allowing of a greater transudation of albumin. In this way he would explain the albuminuria of heart disease, where there is a low blood-pressure and where venous stasis in the kidney increases the pressure in the tubules. The persistent albuminurias are, of course, due to morbid changes in the renal tissues, but are also much influenced by pressure. He refers, in confirmation of his views, to the observations of Hermann and Overbeck, who showed that albumin appeared in the urine whenever one interfered with the flow of blood to the kidneys in a purely mechanical manner by compressing the renal arteries, or the abdomenal aorta above their origin. The albuminuria disappears whenever the blood is allowed to resume its course.

Certain albuminous matters filter more easily than serum-albumin (as egg-albumin and hæmatocrystalin), and hence these substances may appear in the urine when the kidneys are sound, and the blood-pressure normal.

LAUDER BRUNTON AND POWER—ON THE ALBUMINOUS SUBSTANCES WHICH OCCUR IN THE URINE IN ALBUMINURIA. *St Bartholomew's Hosp. Rep.* xiii. 1877.

In this research the authors endeavour to distinguish the various albuminous substances by determining their coagulating points. The method simply consisted in holding a thermometer in the urine while it was being gently heated in a test-tube over a spirit-lamp, and noting the temperature at which the urine began to grow milky from commencing coagulation. It was found that the presence of urea raised the coagulating point of solutions of serum-albumin, whereas it was lowered by uric acid, other acids, and neutral salts. It is, therefore, evident that urea will more or less counteract the effect of acids and salts in the urine upon the coagulating point of the albumin it contains.

At one time they may exactly neutralise each other, at another the coagulating point may be considerably above or below that at which the albumin would be precipitated from a purely aqueous solution.

The general results arrived at are—That there are various albuminous bodies which appear in the urine. Some of these are derived from the digestive canal and others from the blood, of which they form ordinary constituents. Those derived from the digestive canal may be either albuminous substances absorbed without undergoing digestion, as, for example, the white of raw eggs, or peptones. The albuminous substances derived from the blood are paraglobulin and serum-albumin. The former is only in small quantity. The effect of food is to increase the quantity of albumin, or even to make it appear when it is absent during fasting. Its effect on the coagulating point is not constant, though it generally lowers it. No pepsin was found in the urine, but evidence was obtained of the presence of pancreatic ferment (trypsin).

The indications which the coagulating point of the urine affords are as yet not decisive as to the nature of the disease, but the authors hope to be able to make further observations which may lead to a more practical result.

REPORT ON RECENT PHYSIOLOGICAL PAPERS.

By G. T. Beatson, B.A. (Cantab.), M.D. (Edin.)

On the Physiological and Therapeutical Properties of Glycerine, By A. Catillon. *Archiv. de Physiol.* No. 2, March–April 1878.

In a previous communication the writer showed that glycerine, when taken internally, causes a marked diminution in the quantity of urea excreted each day; while it raises the temperature, and, if persevered in for some time, increases the bodily weight. He also demonstrated that it is entirely absorbed, none of it being found in the blood, and only a slight trace of it in the urinary secretion. From these facts the author concluded that the increase of temperature in the body, while the excretion of urea was diminished, pointed to the combustion of the glycerine in the blood. This fact also explained the increase in bodily weight; for the respiratory process, with its attendant combustion, being carried on at the expense of the glycerine, the nitrogenous and fatty materials were unused, and so added to the bodily weight. But as the ultimate products of the combustion of glycerine are carbonic acid and water, we ought to find a larger proportion of this substance in the expired air, after the administration of glycerine, if it serves as material for the respiratory process. With the object of investigating this point, the author carried on, in the laboratory of M. Vulpian, a series of experiments on dogs, care being taken to avoid any influences exerted by food, and the glycerine being given either diluted with water or with a few crusts of bread in it. A simple but effectual apparatus was employed for the collection of the expired air. In the first experiments it was found that the administration of glycerine distinctly increased the percentage of CO_2 in the expired air as compared with the amount given out before when no glycerine had been taken. The next experiments were to test the influence of glycerine on the number and volume of the inspirations, and it was found that, while the number of respirations was not materially altered, their volume was, and the absolute quantity of CO_2 given out during this time was much increased. The next series of experiments was to see if the crusts of bread added to the glycerine in any way affected the results, and it appeared that they had no appreciable effect on the amount of CO_2 eliminated. More copious feeding increased the CO_2, but did not bring it up in any way to the proportion eliminated after the administration of the glycerine. These different experiments go to prove that glycerine is consumed in the system, the amount of CO_2 in the expired air almost equalling the amount of C in the glycerine. Before concluding, the author demonstrates that glycerine is changed directly into CO_2 and H_2O, and that there are no intermediary products, such as formic and oxalic acids, and he also considers whether glycerine, like alcohol, may not be deposited in certain organs of the body. With the view of elucidating this point,

he examined the blood, brain, liver, kidneys, and spleen of dogs fed on glycerine, and in none of them could the presence of glycerine be detected. The following are the author's conclusions:—(1) After the administration of glycerine the percentage of Co_2 in the expired air is manifestly increased. (2) This increase is more marked, and lasts longer, the larger the quantity of glycerine. It commences about one hour after the administration is at its height—*i.e.*, in from three to four hours—and lasts five to ten hours. (3) Further, it is clear the absolute quantity of CO_2 is increased, and in such proportions that we can almost recover in this form the whole amount of C contained in the glycerine. (4) The number of inspirations remains the same, but their volume is increased, and this lasts even when the percentage of CO_2 has become normal, probably from the stimulus and movements to which the respiratory organs have been subjected. (5) This increase of CO_2 is seen in a pneumonic dog as well as in an emphysematous one, the volume of whose inspirations was weak. (6) The conversion of the glycerine into CO_2 and H_2O is a direct one, and there are no intermediate products, as formic or oxalic acid. (7) Unlike alcohol, which some investigators have found to pass out of the body unchanged, and to be deposited in certain organs, as the brain and liver, glycerine is entirely got rid of as CO_2 and H_2O, and is deposited in no organs. (8) Lastly, these experiments seem to throw some light on the combustion of hydrocarbons in the body. Thus, we do not know whether sugar is burned directly in the blood, or undergoes first the alcoholic or lactic fermentation, but as the chemical composition of glycerine approaches nearer to that of sugar than alcohol, the conditions under which the combustion of the former is brought about may be explained by what happens to glycerine.

ON THE PHYSIOLOGICAL ACTION OF COMPRESSED AIR.

In the *Archives de Physiologie* for January–February 1878, Dr Bacchi has given an analysis of the experiments and observations of A. Mosso of Turin on this subject, which are opposed to the generally received mechanical theory of Vivenot, according to which the increase of atmospheric pressure drives the blood into the internal parts of the organism, and this increased peripheral resistance is the cause of the slowing of the heart's action. The experiments of Dr Mosso were carried out at Milan on a young healthy man, aged 26, whose normal condition was well known, and they were all made at 760 mm. above the ordinary pressure. In the first series of experiments it was found that the volume of the fore-arm decreased 5–11 cc. on the first admission of the compressed air, but during the gradual increase of the pressure to 760 mm. there was no diminution in the size of the fore-arm, although sometimes there was observed some diminution if the pressure was still further increased. Lowering the pressure brought about a considerable diminution in the volume of the fore-arm. While the pressure lasted, speaking, or even the presence of other people, would have some effect on the size of the fore-arm. The circulation was less vigorous during the decrease of the pressure,

and the size of the arm increased immediately the pressure had become normal. On all these grounds, Mosso concludes that the mechanical theory of Vivenot is not correct. All these experiments on the peripheric circulation were made with the pletismograph.

The next experiments were in reference to the changes in the pulse, the sphygmograph being employed. It was found that there was not a constant diminution in the pulse during the increase of barometric pressure, but that there was a diminution as soon as it began to decrease. Mosso, however, observed some variations in the frequency of the pulse during the increase and diminution of the pressure, and he thinks we must attribute them to the chemical action of the compressed air on the nerves of the heart; and he thus accepts for man the chemical theory of M. P. Bert, who considers that changes in the barometric pressure have no physical mechanical effects on animals, but exclusively act from a chemical point of view. The last series of experiments were made with the object of determining the effects on the respiration of the compressed air, and it was found there was an increase in the number of the respirations, and slightly in the volume of the inspirations, but nothing sufficient to show a mechanical dilation of the lungs, according to the theory of Vivenot, for it was found that in the intervals between two sittings the patient's inspirations increased in volume under the ordinary barometric pressure.

On the Part Played by the Cerebro-Spinal Fluid in Cerebral Injuries. By M. H. Duret. *Archiv. de Physiolog.* No. 3.

The paper is a lengthy one, and entirely experimental. It is taken up with a consideration of what the author terms "cerebro-spinal shock," by which he understands the complete abolition of all brain functions, following immediately on some cranial blow, and caused by the cerebro-spinal fluid transmitting the injury to the different parts of the brain which are able to produce the symptoms observed. After detailing the circumstances which drew his attention to the influence of the cerebro-spinal fluid in injuries, and after giving a very full anatomical and physiological account of the distribution of the fluid in the nervous system, accompanied by simultaneous tracings of the pulse, the respiration, and the pulsations of the brain, the author recounts very fully his experiments, which were made on dogs, horses, and rabbits, and consisted either of blows inflicted directly on the skull, or of injections of different substances through openings in the skull-cap. The results of these experiments may be summed up as follows:—

1. In the case of a fall on the head or of a blow on the cranium, at the moment of impact there is set in motion a liquid wave round the hemispheres and in the ventricles, which transmits the violence into all parts of the nervous system, and especially against the medulla oblongata.

2. The injurious effects of this fluid wave are shown chiefly in the collections of fluid at the base of the brain, around the neck of the medulla, and on the restiform bodies.

3. At the instant of the injury, from the excess of tension around the vessels, there results a momentary anæmia of the nerve centres in their entirety, which is increased and lengthened by a reflex vascular contraction, due to the irritation of the restiform bodies, and which is followed by a general vascular paralysis, hindering all changes between the blood and the nervous elements, and thus suspending the brain functions. It may even go on to an inflammatory reaction, and the nervous symptoms may last until death, should that be the termination.

4. Clinically we have three sets of cases: one so slight that the symptoms soon pass off, another where they are of medium gravity, and a third where they are so severe that death ensues at once from the sudden anæmia of the medulla oblongata. It is the cases of medium gravity that we have chiefly to consider, and in them it will be found that the symptoms may be divided into two periods. During the first period they are at the commencement of a spasmodic or tetanic type, due to the general anæmia of the nervous system from vascular spasm; but these are followed by those of a paralytic nature, with insensibility and coma. In the second period we have congestive reaction and inflammation, as shown by the pulse, the respiration, and the elevation of temperature.

5. The seat of the lesion, whether frontal, lateral, or occipital, exercises a great influence on the symptoms observed, each locality producing special and characteristic ones, and which are of service both as to diagnosis and prognosis.

6. When local lesions exist, they reveal themselves by special symptoms, which stand out apart from the general symptoms of shock. Thus, lesions of the motor regions show themselves by paralysis, confined to one group of muscles, over which preside the injured centres, or, perhaps, they may commence in this one centre and invade the others, producing epileptic attacks. So, also, injuries of sensory regions are indicated by hyperæsthesia, or anæsthesia, or spasms and reflex contractions in the muscles and the vessels.

7. The strongest analogy exists between the shock inflicted by the cerebro-spinal fluid and that due to hæmorrhage.

On the Modifications Produced by the Animal Organism on Different Albuminous Substances Injected into the Vessels. By MM. J. Béchamp and E. Baltus. *Annales de Chimie et de Physique*, August 1878, vol. xiv.

The subject of this paper is the pathology of albuminuria, in reference to the question whether it is caused by the quantity of albumen in the blood, or by the quality of it. Their experiments, which were conducted on dogs carefully fed, and so placed that their urine was readily collected, tend to show that the quality or molecular condition in which the albumen exists is really the point which determines the presence of albumen in the urine. After pointing out how previous investigators have not paid sufficient attention to the fact that the different albumens are really distinct substances with varying chemical

properties, and have really experimented with albuminous compounds of a very complex character, they proceed to show that in all cases the exact characters of the eliminated albumen should be taken, and that the only safe and reliable way of doing this is by obtaining its rotatory power. The ordinary reactions of heat, nitric acid, or alcohol, are not trustworthy. The general scope of the experiments was extensive. They first repeated previous experiments in which natural albuminous materials, as the serum of the blood and white of egg, had been used for injection into the blood. They next employed albumens of definite physical and chemical characters—pure zymase, peptones, and certain albuminates. The first point they established in their experiments was that there is, even in healthy urine, a small quantity of an albuminous material, which, in 1865, M. Béchamp had drawn attention to, and which he then termed "nefrozmase." The next matter investigated was to ascertain if the mere act of injection, or the quantity of water holding the albuminous substances in solution, had anything to do with the symptoms observed afterwards, and it was found that they had not. Proceeding, then, with their injections into the blood of different albuminous substances, such as the albumen of blood serum, the 3-plombic albumen of the egg, the 6-plombic albumen of the serum of the cow's blood, gelatine, and other forms, they found that, after injection, the albumens may be divided into two groups. The first group contains the albumen of blood serum, the 3-plombic albumen of the egg, the 6-plombic albumen of the serum of the cow's blood, and gelatine, all of which remain in the blood. The other group contains the white of egg and the 6-plombic albumen of the white of egg, both of which are eliminated by the urine, though not in the same quantity as they were injected.

The 3-plombic albumen of egg is obtained by precipitating diluted egg albumen with the tri-basic acetate of lead solution of the French Pharmacopeia; while the 6-plombic albumen is obtained from the above filtrate by adding acetate of lead solution, which has been converted into a 6-basic compound of lead by the addition of ammonia.

Reviewing their experiments, the authors conclude that the quality of the albumen, and not its quantity, determines its behaviour in the system after injection; that, of the albumens eliminated by the urine, the white of egg is the only one that has undergone no change in the economy; that the injection of some forms of albumen into the system is productive, sometimes of severe constitutional disorders, even occasioning death, as in the case of gelatine; and that, as a rule, the urine of animals that have been experimented on by injection is alkaline.

On the Physiology of the Vesical Epithelium. By MM. P. Cazeneuve and Ch. Livon. *Compt. Rendus*, No. 12, September 16, 1878.

Various opinions are held as to the power of absorption possessed by the mucous membrane of the bladder. Some consider its absorptive power very great (Segalas); others think it very feeble (Bérard, Demar-

quay); and a third class deny its existence (Kuss, Morel, Susini). Previous investigations have usually consisted in injecting poisonous drugs into the bladder and observing the results; but the authors of the present communication have adopted a new method of investigation, the principle of which is to establish whether or not any urea, the chief urinary ingredient, passes through the walls of the bladder. Their "modus operandi" is to tie the prepuce of a dog for some hours before the operation, so as to keep the urine in the bladder. They then expose this viscus, remove it full of urine by means of a ligature, and, after washing it externally with distilled water, they plunge it into three quarts of distilled water at a temperature of 25° C. From time to time the water outside is tested by means of hypobromite of soda, which indicates, by effervescence, the presence of urea. In a series of twenty experiments it was found that it took from three to four hours for the urea to pass through, in the case of a bladder freshly removed; but in one taken out the previous evening, dialysis occurred in from ten to fifteen minutes. The results of their numerous experiments may be summed up as follows:—

1. Desquamation of the vesical epithelium, brought about by any mechanical means, as from the blunt point of a sound, is followed by vesical permeability, and in this point they corroborate Kuss, who holds that the impermeability of the bladder is due to a peculiar property of the vesical epithelium.

2. The increase or diminution of the temperature of the body affects the characteristics of the epithelium, for in an animal well fed the function of the epithelium is very marked, while in one that had been starved it lasts only a very short time after death.

3. Injuring the kidneys, or cutting the spinal cord, affected the physiological properties of the vesical epithelium in a very marked degree.

Excessive Perspiration not necessarily associated with Increased Cutaneous Circulation.

In a communication to the *Compt. Rendus*, No. 14, September 30, 1878, M. Vulpian draws attention to this point. He first notices that experiments support the clinical fact, often observed, that the phenomena of perspiration are not necessarily linked with changes in the cutaneous capillary circulation. Thus in cats, whose abdominal aorta has been tied, stimulating the sciatic nerve by an induction current (Ostrumoff), or injecting chlorohydrate of pilocarpine into the jugular vein (Luchsinger), produces perspiration on the toes of the hind limbs in the first case, and on all the extremities in the latter case. He next shows that we must reject as valueless the statement of Adamkiewicz that perspiration can be produced on the toes of young cats three quarters of an hour after death, by stimulating a section of the spinal cord; and in fact he finds that stimulation of the medulla oblongata does not excite so much perspiration on the digital extremities as direct faradisation of the mixed nerves which supply them.

In concluding, he points out that the abundant secretion of perspira-

tion seen on the digital pulps of a posterior extremity, under the faradisation of the peripheral end of the recently divided sciatic nerve, coincides with a marked contraction of the vessels of the whole limb, and with a consequent diminution in the blood supply to it; and also that the perspiration which is observed on the digital pulps of cats, at the moment of death, is preceded by a bloodless condition of them, due to the temporary stimulus which is set up in the nerve centres by the rigidity or torpor of death. That this occurrence is due to a stimulus from the nerve centres can be shown conclusively by cutting the sciatic nerve of an extremity before studying the phenomena in question, and it will be found that at the moment of death perspiration will appear on all the digital pulps, with the exception of that one whose sciatic nerve has been cut.

On the Influence exerted on the Irritability of Muscles by the Quantity of Blood contained in them. By M. J. Schmoulewitsch, in the *Compt. Rendus*, No. 10, September 20, 1878.

While admitting that the close connection between the circulation of blood in the muscles and the exercise of their function is shown by such facts as the paralysis of the posterior limbs, which follows ligature of the abdominal aorta (Stevson), and by the restoration to contractility, which injection of arterial blood causes in stiffened muscles (Brown-Séquard), the author of this paper draws attention to the fact which has come under his notice, that muscles in becoming anæmic do not at once lose their irritability. On the contrary, the irritability increases for some time, and then, on reaching a certain point, begins to decline. The same phenomenon has been observed after section of a nerve, no doubt from the anæmia which section of the nerve induces, for we know that muscular nerves contain some vaso-motor fibres (Cl. Bernard) and the section of the nerve is a mechanical stimulation to these fibres, and they cause contraction of the vessels, with consequent anæmia.

The two facts which the author relies on for proving that the increased irritability of the muscles arises from anæmia, are (1) that ligature of the artery supplying a muscle prevents any increase of irritability after section of the nerve; and (2), in a curarised animal, where there is almost complete paralysis, section of the nerves causes an increase of muscular irritability, acting through the vaso-motor nerves, which are scarcely at all acted on by curara.

On the Albumens in Hydrocele. By M. J. Béchamp, in *Compt. Rend.* No. 2, July 8, 1878.

The points brought out in this paper are that albumens differ very much in their rotatory power, that they are isomeric (having the same percentage composition, but differing in their chemical and physical properties), and that they vary in their composition according to the cavity of the body in which they occur, this variation being due to a

special power possessed by the tissues of the living body of modifying the albumens, which they secrete. The fluids from five cases of hydrocele had all characters in common, but differing entirely from those of the albumen of the blood. Thus, they had the same rotatory power, they reddened on the addition of a solution of mercuric nitrate (Millon), and they all turned violet on the addition of hydrochloric acid, beside other points of resemblance. These observations show that the tissues modify in a particular way the albumens of the blood which traverse them, and we must admit that it is a remarkable point that the tunica vaginalis should always secrete the same form of albumen, not only in different persons, but in the same person at different times, for some of these fluids were taken at different intervals of time. It shows that the function of this membrane is peculiar to itself.

ON THE RATE OF THE NERVE CURRENT IN THE MOTOR NERVES OF MAMMALS. By M. CHAUVEAU, in the *Compt. Rend.*, Nos. 3 and 4, for July 15 and 22, 1878.

The author was led to undertake these investigations by finding that the results obtained by Helmholtz on dead frogs were not applicable to living mammals,—the rate of the nerve current in them being three times as great as in the dead frog. The method used in the investigations was the graphic method, and a most accurate chronograph was employed for marking the moment when the contractions are excited, and the time when the stimulus is applied,—the difference between the two indicating exactly the rapidity with which the nerve current travels the length of the nerve included between the stimulated points. To obtain the necessary quiescence on the part of the animals experimented on, they were brought lightly under the influence of chloral, or artificial respiration was kept up after section of the bulb, it being found that neither of these conditions interfered with the results. The induced current was employed along with the single polar method, great care being taken in its application. To ensure uniformity in the stimuli, a special instrument, termed a self-acting distributor (*distributeur automatique*), and which is set in motion by the cylinder for registering, is employed. Each turn of the cylinder causes the distributor to apply the current at a different point of the nerve. Further, the cylinder sets in motion an apparatus for recording on the surface of the cylinder the results, which it does in wavy but continuous and distinct lines. Space does not allow of describing in detail the recording instruments; but we may note that the cylinder will register a period of $\frac{1}{24,000}$ of a second, equivalent to a space on the paper of $\frac{1}{2}$ mm. or less; that the curves of the vibrations of the tuning fork for marking the time have on the paper a space not less than 2 mm. in length; that the opening of the induction circuit is determined at a given moment by the motion of the cylinder, and an electro-magnetic signal marks on the paper the moment in which the stimulus of the induced current is brought into action; and that the contractions are recorded in every case for transmission by a myographion. From among the domestic animals of high stature the

author selected the horse, on account of the great length of the laryngeal nerves in it. The nerves experimented on were the pneumogastric, the recurrent laryngeal, and the facial. In addition some observations were made on the sciatic nerve of a frog. The results of these investigations may be summed up as follows :—

1. The mean rapidity of the nerve current in frogs was about 21 metres per second.

2. In the pneumogastric nerves of the horse there were differences in the rate of the nerve current at different points in the same nerve, and also in the different animals experimented on.

3. The differences in the rate of nerve current at different points in the same nerve is explained by the fact, that the stimuli travel less rapidly the nearer they approach the end of the nerve, the power of conductivity decreasing from the origin to the termination of the nerve.

4. The differences found in different animals was due to the state of health and physique of the animal. The current was much quicker in those of strong physique, and slower in those who were weaker, and who were long under the anæsthetic.

5. Taking the average rapidity of the nerve current, it was found to be about 65 metres per second, or more than three times greater than in the motor nerves of the frog. In some of the strong animals the rapidity reached 75 metres, while in others it was as low as 40 metres.

6. In *post-mortem* experiments the law about the conductivity of the nerve decreasing from the origin to the termination of the nerve is reversed, and thus is explained the differences in results obtained from experiments on frogs' nerves.

7. After section of the vagus nerve the conductivity is sensibly diminished, and the results must be slightly modified.

8. All the above points were confirmed in the experiments on the facial nerve.

Experimental Researches on the Sweat Nerves of the Cat. By M. A. Vulpian, *Compt. Rend.*, No. 8, August 19, 1878.

In this paper the author states that he has repeated the experiments of Luchsinger on the sweat nerves in the cat, and can confirm them in all particulars. Luchsinger's experiments consisted in the injection of a small quantity of chlorohydrate of pilocarpine beneath the skin of a cat, one of whose sciatic nerves had been divided. The result of this was the appearance of copious perspiration on the digital pulps of all the limbs. When this injection was repeated on the same cat two hours after section of the nerve, the perspiration was more abundant on the pulps of the limbs whose nerves were intact, and if the injection was once more repeated six days after section of the nerve, no perspiration appeared on the claws of the limb whose nerve was cut, but only on the other feet. The conclusions Luchsinger drew from these facts were, that the pilocarpin acts on the terminations of the perspiratory apparatus, and that the secreting elements of the sudori-

parous glands themselves lose their excitability six days after severance from the nerve centres. Continuing his investigations in this matter, Vulpian found that neither the induced current applied to the peripheric end of the cut sciatic nerve, nor faradisation of it had any effect; but if some cc. of an infusion of jaborandi were injected eight days after section of the sciatic nerve, the application of electricity induced a copious flow of perspiration on the digital pulps of the limb whose nerve was cut. Section of the abdominal sympathetic in no way affected the action of the pilocarpine, thus supporting Vulpian's view, that all the sweat-producing nerves of the limbs are not contained in the abdominal sympathetic.

Extending his observations to the anterior limbs, he found that the same effects followed the section of the brachial plexus as of the sciatic, and that removal of the superior thoracic ganglion had no more effect than section of the abdominal sympathetic. From this it follows that the view that all the sweat-producing nerves for the anterior limbs comes from the superior thoracic ganglion (Luchsinger, Nawrocki), is not correct.

On some Phenomena of Vaso-Motor Action observed in the course of Investigations on the Physiology of the Excito-Secretory Nerves. By M. Vulpian, in the *Compt. Rend.* No. 11, September 9, 1878.

The author draws attention to the following points of interest:—

1. That marked congestion of the skin of the lower part of the limb, accompanied by a corresponding elevation of temperature, follows section of the sciatic nerve of the limb, of the brachial plexus, and of the roots of the sciatic and brachial plexus in the spinal canal. The same phenomena are also observed after excitation of the superior thoracic ganglion of the same side, or section of the abdominal sympathetic. The effects, however, are not equally permanent in all these experiments, and they are eventually followed by marked pallor.

2. When the digital pulps of the foot, whose nerve has been cut, become congested, those of the other foot on the same side become pale.

3. Faradisation of the peripheral end of the cut sciatic nerve, on the day of the operation, causes a transient superficial pallor, due to contraction of the vessels, followed by congestion, which is less marked than before.

4. Faradisation of the central end of the cut sciatic nerve is invariably followed by slight congestion and perspiration of the digital pulps of the toes, whose nerves are intact.

5. Some days after section of the sciatic nerve, or brachial plexus, and when the pallor and anæmia are well marked, slightly rubbing the digital pulps of the limb with the hand will cause some congestion, no doubt of a reflex nature and due to reflex vaso-motor dilatation. No perspiration, however, is seen.

6. After an intra-venous injection of jaborandi, faradisation of the lingual nerve, after section, causes an increased flow of saliva, no

doubt from the fact that the lingual nerve, in consequence of its anastomosis with the corda tympani, is, from the vaso-motor point of view, chiefly a vaso-dilator nerve.

7. When an animal is fully under the influence of curara there is a cessation of the action of the sudoriparous glands, and the tips of the digital pulps of the limbs become rosier in colour, which congestion is more marked after section of the sciatic nerve or excision of the superior thoracic or cervical ganglion. Curara used some days after these last operations has no effect, except on the limbs whose nervous supply is intact.

8. If the sciatic nerve of a limb is cut, jaborandi or pilocarpine increase the congestion which usually accompanies the first appearance of the perspiration.

9. In some old cats we can easily bring about the different vaso-motor influences of contraction and dilatation, but we cannot excite perspiratory action by any of the ordinary means.

10. After the administration of sulphate of atropia, the various vaso-motor actions may be called forth, but there is not the slightest sign of perspiratory action.

Comparison between the Salivary and Sudoriparous Glands as regards the Effects of Section of their Excito-Secretory Nerves. By M. Vulpian, in the *Compt. Rendus*, No. 9. August 26, 1878.

The point sought to be elucidated was whether the same rule is applicable to the submaxillary as to the sudoriparous glands, in reference to the action of jaborandi and its alkaloid pilocarpine on them, after section of their excito-secretory nerves. The experiments were made on curarised dogs, and consisted of section of the lingual nerve above where the chorda tympani is given off to the submaxillary gland, of excision of the superior cervical ganglion, and of section of both chorda tympani nerves and the secreting fibres of the sympathetic in the same animal. After some days, intravenous injections of jaborandi were used, and the result obtained by these experiments showed that while section of the sciatic nerve in a limb affects the sudoriparous glands of it, section of the excito-secretory nerves of the submaxillary ganglion does not interfere with its action. Jaborandi still acts on the gland several days after section of the excito-salivary nerves, while it has no effect on the sudoriparous glands six days after section of the sciatic nerve. No decided opinion as to the cause of this difference can be given, and more investigations are required, but Vulpian thinks it may be accounted for by the dissimilarity in the anatomical elements of the glands, or to a difference in the glandular circulation brought about by the section of the nerves, or that it may be due to the great number of nerve cells scattered along the whole length of the secreting nerves of the submaxillary gland, either singly or in ganglionic masses, these cells, after section of the nerves, hindering very probably the nerve fibres from losing by degrees their excitability as far as their peripheral ends. One other point of interest was brought out in these

experiments. With the view of ascertaining if the submaxillary gland had any other sources of nerve supply beyond that of the chorda tympani nerve and the sympathetic fibres, the right lingual nerve was cut above the chorda tympani nerve and the superior cervical ganglion was excised. The sciatic nerve was then faradised, and it was found that while there was a copious flow of saliva on the left side where the nerves were intact, there was none on the right side.

ON A PUSTULAR DISEASE CAUSED BY AN ATMOSPHERIC GERM. By M. H. TOUSSAINT, in the *Compt. Rendus*, No. 2, July 8, 1878.

In this communication the author details some experiments made on rabbits with the blood of a horse that had died with all the symtoms of charbon or malignant pustule. To the naked eye the blood presented no peculiar characters, and microscopically its corpuscles seemed normal, and it showed no signs of vibrios or bacteria. The experiments were made with one-tenth to half a drop of blood, or with an artificially prepared fluid containing some of the blood. In the first cases experimented on, the blood had been obtained sixty hours previously from the horse. No less than fifty-four animals were experimented on, and in all death took place; and the lesions found after death were very similar. Death usually occurred from the tenth to the fourteenth hour after the injection, the temperature varying from 37° to 39°. Of the symptoms observed, diarrhœa was a very constant one. On *post-mortem* examination, cadaveric rigidity was very slight, and the muscles were pale; but throughout the body a striking feature was the extreme injection of all the small vessels, which were gorged with dark blood. In the intestines the small intestine was found completely stripped of its epithelium, and Peyer's patches were congested, and often studded with hæmorrhagic spots. The microscope, with a power of 500 to 800 diams., revealed the interesting point that not only the blood, but all the other tissues and fluids of the body were full of extremely small vibrios, of spherical or slightly oval shape, with scarcely any refractive power. They were generally single, and there were never more than three grouped together, and their movements were very slow and feeble. In size they were from $\frac{1}{10,000}$ mm. in thickness, and in length from $\frac{5}{10,000}$ to $\frac{10}{10,000}$ mm. They were seen everywhere in the tissues and fluids, and outside the vessels, and with a very high power they could also be seen inside the vessels like masses of granulations, often completely closing up the capillaries.

It was found that all the fluids of the dead rabbits had the same inoculative power as the blood, and facts observed showed that the disease was not only contagious by direct inoculation, but also probably by the digestive and respiratory tracts; for rabbits that had eaten food mixed with the excrement of the innoculated rabbits, or had been in the same compartment with them, died within a short time.

The author also studied this new germ, and watched its history under cultivation. He ascertained that in two hours and a half, by means of fission, a single one produces twenty-two others; but they

never assumed the filamentous form like bacteria, and they increased more rapidly at the edges than at the centre of the fluid.

M. Toussaint thinks that this disease is probably the same as that described by MM. Leplot and Jaillard as malignant pustule without the presence of bacteria, and which has been studied by M. Devaine, and described in a former number of the *Compt. Rendus*.

On Charbon or Malignant Pustule in Fowls. By MM. Pasteur, Joubert, and Chamberlaud, in the *Compt. Rendus*, No. 2, July 8, 1878.

In a previous paper read before the French Academy, these gentlemen showed that it was possible to excite this disease in fowls, under the application of cold, the lower extremities being immersed in water of a temperature below that of the body. Following up this line of inquiry, they have demonstrated the converse of their previous experiments, and have shown that while the disease can be established under the influence of cold, it may be arrested aud cured by the timely application of warmth. The points that their investigations have clearly established are:—

1. That fowls are not susceptible of the disease.
2. That under the influence of cold they easily contract it.
3. That by lessening the degree of cold in the case of those in whom the disease has been established, they can be completely cured by the application of warmth, the bacteria being absorbed.
4. That in those cases where the blood was largely impregnated with the germs of the disease, as in the last hours of life, no cure could be obtained.

On the Power of Compressed Oxygen to deprive Blood of its Septic Condition. By M. V. Feltz, in the *Compt. Rendus*, No. 3, July 15, 1878.

Some years ago (1875) the author of this paper showed that the exposure of putrid blood to the influence of oxygen for some days seemed to lessen its toxic influence, chiefly by diminishing the movements of the vibrios. Afterwards (1877) he proved that pure oxygen, at high tension, was able to kill the oscillating rods and vibrios of putrid blood in thirty-five days, but had no effect on the corpuscular germs or conical spores to which the blood owed its septic power. All these facts are in harmony with M. Pasteur's views; but, in an important work on barometric pressure, M. Paul Bert has shown that by employing oxygen at a high tension for a longer time, it will destroy even the germs which give septic properties to the blood, as well as the vibrios.

On the Theory of Fermentation. By M. Pasteur, in the *Compt. Rendus*, No. 4, for July 24, 1878.

This communication was called forth by the appearance, in the *Scientific Review*, of an article which was said to embody the latest

opinions of Claude Bernard on the alcoholic fermentation. The papers containing these opinions were found accidentally by M. d'Arsonval among those left by the illustrious physiologist, and were dated October 20, 1877. They expressed entire disbelief in the truth of Pasteur's theory. In the present paper Pasteur gives his views as to the interpretation to be put on these papers, believing, as he does, that they bear quite a different one to that suggested by M. Berthelot, who published them. After remarking that it is strange that Claude Bernard, who was in constant intercourse with him, and also present at the meetings of the Society, had never given the slightest hint that facts had occurred to make him change his views on the fermentation theory, Pasteur is of opinion that these papers, found after his death, were mere jottings as to the plan he meant to follow in investigating the subject, for it was known that he purposed doing so. And the plan he evidently intended to follow was to start with the assumption that he (Pasteur) was wrong in his views, and by making a series of experiments, founded on this assumption, to prove him right. Such is the explanation put forward by M. Pasteur, as the one best in harmony with all the facts of the case; but in another paper, meant as a reply to this communication of Pasteur, M. Berthelot states that the observations preceding the notes completely establish their character, and show them to be the results of the different experiments that it was known Claude Bernard had made on the subject of alcoholic fermentation.

REPORT ON RECENT MEMOIRS ON THE ANATOMY OF THE BRAIN.—By Professor TURNER.

1. AD. PANSCH.—Ueber gleichwertige Regionen am Grosshirn der Carnivoren und der Primaten. *Centralblatt.* 1875. No. 38.
2. ——— Einige Sätze über die Grosshirnfaltungen. *Centralblatt*, 1877. No. 36.
3. ——— Bemerkungen über die Faltungen des Grosshirns und ihre Beschreibung. *Archiv für Psychiatrie.* Bd. viii., Heft. 2.
4. ——— Einige Bemerkungen über den Gorilla und sein Hirn.
5. ——— Die Furchen und Wulste am Grosshirn des Menschen, Berlin, 1879.
6. PANSCH and BOLAU.—Ueber die menschenähnlichen Affen des Hamburger Museums. *Abhand. aus dem Gebiete der Naturwiss.* Hamburg, 1876.
7. WEISBACH.—Die Supraorbitalwindungen des menschlichen Gehirns. *Wien. Med. Jahrbücher.* Bd. xix., 1876.
8. CARLO GIACOMINI.—Una Microcefala. Turin, 1876.
9. ——— Guida allo studio delle Circonvoluzioni Cerebrali dell' Uomo. Turin, 1878.
10. ——— Topografia della scissura di Rolando. Turin, 1878.
11. ——— Nuovo processo per la Conservazione del Cervello. Communicazione alla Reale Accademia di Medicina di Torino. 1878.
12. PAUL BROCA.—Sur la Topographie Cranio-cérébrale. *Revue d' Anthropologie*, 1876. T. v., No. 2.
13. ——— Étude sur le Cerveau du Gorille. *Revue d' Anthropologie*, t. i. 2e series.
14. ——— Nomenclature cérébrale. *Revue d' Anthropologie*, t. i., 2e series, April 1878.
15. ——— Anatomie Comparée des circonvolutions cérébrales. *Revue d' Anthropologie.* 1878.
16. CH. FÉRÉ.—Note sur quelques points de la Topographie du Cerveau. *Arch. de Physiologie*, p. 247. 1876. *Mém. de la Soc. de Biologie*, 2 ser. iii.
17. A. PITRES.—Note sur la Nomenclature des différentes régions du centre ovale des Hemisphéres Cérébraux. *Archives de Physiologie*, p. 245. 1877.
18. TH. W. VON BISCHOFF.—Untersuchungen der Eingeweide und des Gehirns des Chimpansé—Weibchen. *Mittheilungen des Kgl. Zoolog. Museum. zu Dresden*, Heft 2.
19. ——— Ueber das Gehirn eines Orang-Outan.—*Sitz des K. Bayer. Akad. d. Wissensch.* 1876.
20. ——— Ueber das Gehirn eines Gorilla und die untere oder dritte Stirnwindung der Affen. *Sitz des K. Bayer. Akad. d. Wissensch.* 1877.
21. ——— Das Gorilla—Gehirn und die untere oder dritte Stirnwindung. *Morpholog. Jahr.* p. 59. 1878.
22. HESCHL.—Die Tiefen-Windungen des menschlichen Gehirns und die Ueberbrückung der Centralfurche. *Wiener Med. Wochenshr.* 1877, No. 41.
23. A. ECKER.—Zur Kenntniss der Wirkung des Skoliopædie des Schädels auf Volumen, Gestalt und Lage des Grosshirns. Braunschweig. 1876.
24. ——— Ueber die Methoden zur Ermittelung der topographischen Beziehungen zwischen Hirnoberfläche und Schädel. *Arch. f. Anthropol*, x. p. 233.

25. M. Benedikt.—Der Raubthiertypus am menschlichen Gehirns. *Centralblatt.* 1876. p. 930.
26. ——— Der Hinterhaupts Lappen der Säugethiere. *Centralblatt.* 1877. p. 161.
27. Th. Meynert.—Die Windungen der convexen Oberfläche der Vorderhirns bei Menschen, Affen und Raubthieren. *Archiv. für Psychiat.* viii. p. 257.
28. Julius Krueg.—Ueber die Furchung der Gross-hirnrinde der Ungulaten. *Zeitsch für Wissensch. Zoologie,* vol. xxxi. 1878.
29. Herbert. C. Major. Observations on the Brain of the Chacma Baboon. *Journal of Mental Science.* January 1876.
30. ——— The Histology of the Island of Reil. *West Riding Asylum Reports,* vi. 1876.
31. ——— Observations on the Structure of the Brain of the White Whale (*Delphinapterus leucas*). *Jour. of Anat. and Phys.* January 1879.
32. B. Lewis and H. Clarke.—On the Cortical Lamination of the Motor Area of the Brain. *Proc. Roy. Soc.* London, 1878, p. 38.
33. Bevan Lewis.—On the Comparative Structure of the Cortex Cerebri. *Brain.* April 1878.
34. C. Richet.—Structure des Circonvolutions Cérébrales. *Thèse.* Paris, 1878.
35. Samuel Pozzi.—Des localisations cérébrales et des rapports du crane avec le Cerveau au point de vue des indications der Trepan. *Archives generales de Médicine.* April, 1877.
36. Bitot.—Essai de Topographie Cérébrale par la cérébrotomie méthodiqua. Paris, 1878.
37. R. L. Heschl.—Ueber die vordere quere Schläfenwindung des menschlichen Grosshirns. Wien, 1878.
38. Daniel Wilson.—Brain—Weight and size in relation to relative capacity of Races. *Canadian Journal.* October 1876.
39. Crochley Clapham.—The weight of the Brain in the Insane. *West Riding Asylum Reports,* vi. 1876.
40. Thomas Dwight.—Remarks on the Brain, illustrated by the description of the brain of a distinguished man. *Proc. American Acad. of Arts and Sciences.* Vol. xiii.
41. W. Turner.—A Human Cerebrum imperfectly divided into two hemispheres. *Jour. of Anat. and Phys.*, xii. January 1878.
42. W. J. Dodds.—The Localisation of the functions of the Brain. *Jour. of Anat. and Phys.*, xii.
43. John Cleland.—The Brain in Cyclopians. *Jour. of Anat. and Phys.*, xii. July 1878.
44. George Rolleston.—Note on the preservation of Encephala by the Zinc Chloride. *Jour. of Anat. and Phys.* January 1879.
45. Victor v. Mihalkovics. —Entwicklungsgeschichte des Gehirns, nach Untersuchungen an höheren Wirbelthieren und dem Menschen. Leipzig. 1877.
46. Gustav Fritsch.—Untersuchungen über den feineren Bau des Fischgehirns mit besonderen Berücksichtigung der Homologien bei anderen Wirbelthierklassen. Berlin, 1878.
47. Burt G. Wilder.—On the Brains of some Fish-like Vertebrates. *Proc. American Ass. Adv. Anc. Science.* August 1876.
48. ——— On the Brain of Chimaera monstrosa. *Proc. Philadelphia Acad. Nat. Soc.* 1877.
49. J. V. Rohon.—Das Central Organ des Nerven System der Selachier. *Denk. Akad. Wissenschaft.* Wien. March 15, 1877.

50. A. H. GARROD.—Notes on the Anatomy of the Chinese Water Deer (*Hydropotes inermis*. *Proc. Zool. Soc.* London, November 20, 1877.
51. ——— On the Brain of the Sumatran Rhinoceros (*Ceratorhinus sumatrensis*). *Trans. Zool. Soc.* x. p. 411, 1878.
52. ——— Notes on the Manatee (*Manatus Americanus*). *Trans. Zool. Soc.* x. p. 137, 1877.
53. H. WELCKER.—Zwei Hülfsmittel bei Demonstration des Gehirns und des Herzens. Virchow's Archiv. vol. lxxiv. p. 500. 1878.
54. D. J. HAMILTON.—A new Method of preparing large Sections of the Nervous Centres for Microscopical Examination. *Jour. of Anat. and Phys.* January 1878.
55. BEVAN LEWIS.—Relationship of Nerve Cells of Cortex to Lymphatic System of Brain. *Proc. Roy. Soc.* London, June 21, 1877,
56. ——— Application of freezing methods to the Microscopic Anatomy of the Brain. *Brain.* Oct. 1878.
57. RUDOLF ARNDT.—Ueber einige bemerkenswerthe Verschiedenheiten im Hirnbau des Menschen. *Virchow's Archiv.* lxxii. p. 37, 1878.
58. ——— Ueber einen eigenartigen anatomischen Befund in dem Centralnerven system eines Geistes-Kranken. *Virchow's Archiv.* lxxiii. p. 196, 1878.
59. E. ZUCKERKANDL.—Beitrag zur Morphologie des Gehirnes. *Zeits. für Anat. und Entwicklungsgeschichte* ii. p. 442, 1877.
60. V. HENSEN.—Beitrag zur Morphologie des Körperform und des Gehirns des menschlichen Embryo. *Archiv. für Anat. und Phys.* 1877, p. 1.
61. E. EHLERS.—Die Epiphyse am Gehirn der Plagiostomen. *Siebold und Köllikers Zeitsch.* 1878, xxx. 607.
62. RABL-RUCKHARD.—Das Central nerven system des Alligators. *Siebold und Köllikers Zeitsch.* xxx. p. 336, 1878.

During the past three or four years numerous important memoirs on the Anatomy of the Brain have appeared, a list of which will be found at the beginning of this article. For the abstracts of Professor Giacomini's Italian memoirs, I am indebted to one of my pupils, Mr T. P. Anderson Stuart; whilst Dr W. J. Dodds has kindly drawn up the abstracts of the memoirs by Fritsch and Rohon.

In this report the following classification of these memoirs has been adopted:—Arrangement of convolutions of human cerebrum; relations of convolutions to surface of head and skull; comparative anatomy of convolutions; minute structure of convolutions; development of brain; malformations of brain; brain weights; methods of preserving and examining the brain; anatomy of brain in fishes.

a. Arrangement of the Convolutions of the Human Cerebrum.

GIACOMINI and PANSCH have each written (9 and 5) a guide to the study of the convolutions of the human brain. The general plan followed by each of these writers resembles that followed by Turner in his *Convolutions of the Human Cerebrum topographically considered*, 1866, and by Ecker in *Die Hirnwindungen des Menschen*, 1869.

In GIACOMINI's guide the results of the most recent observations in embryology, pathology, and comparative anatomy are made use of to clear up many difficulties. Every lobe, fissure, and convolution is described in detail, and at the end of each chapter is a synoptical table

showing on the one hand the name adopted for any particular structure, and on the other hand its many synonyms. The nomenclature adopted is based very much on that of Ecker, and so the terms indicate position as far as possible. At the end is a very complete literature. His experience is, that Féré's statement that a convolution passes across the fissure of Rolando in one per cent. of brains is certainly exaggerated: he has, like Turner, found the fissure of Rolando opening into the Sylvian fissure, and estimates the angle formed by the fissure of Rolando and the vertical at from 115° to 125°. Gratiolet, having observed in a Hottentot's brain a large anastomosis between the inferior and middle frontal convolutions, a condition not usual in white races; and again, having frequently noticed anastomoses between the superior and middle frontal convolutions of white races, and none in the Hottentot's, thought this might be a race character. Subsequent inquiry has not supported this idea, since the condition described by Gratiolet as peculiar to blacks is not unfrequently found in white races. Notwithstanding this, however, in a Moor from Abyssinia lately dissected by the author, two anastomoses were found between the inferior and middle left frontal convolutions, just as Gratiolet described as the rule in the black races; on the right side there was only one such anastomosis, but on both sides the superior and middle frontal convolutions were quite separate throughout. He names the "sulcus præcentralis" (Ecker), the "prerolandic" fissure, and has several times seen it open into the Sylvian fissure, a condition which Ecker says he has never seen. He has never seen a sulcus traversing the superior temporal convolution, and so placing the superior temporal sulcus in communication with the Sylvian fissure. Three cases of partial or complete absence of the corpus callosum are referred to. In the first the corpus existed only in its anterior third, and the convolution of the corpus callosum corresponding to this portion was normal, but the posterior two-thirds of the corpus were reduced to a very thin membrane, and the part of the convolution corresponding was absent. In this posterior portion of the inner surface of the hemispheres, the convolutions were arranged as they are in cases of total absence of the corpus, viz., perpendicular to the calloso-marginal fissure. In the second, only a small part corresponding to the knee-shaped bend existed, the convolution of the corpus was entirely absent, and the other folds of the inner surface were arranged perpendicularly to the hilum of the hemispheres. In the third case the corpus was awanting only in the middle; the convolution of the corpus was entire throughout. In this brain the parts around the fissure of Rolando were atrophied, and so, there being nothing for them to connect, the commissural fibres of the corpus callosum corresponding to these parts were awanting. In the first two cases the lesion was evidently congenital, but in the third it had occurred only after the corpus callosum had reached its full development, and probably following a lesion of the middle cerebral artery, in the area of the distribution of which the lesion was. If these observations are confirmed, then the presence of the convolution of the corpus callosum in after life would indicate the presence of the corpus at birth, and absence of the convolution in after life would indicate

absence of the corpus at birth. In one of these brains there is a well-developed and superficial internal *pli de passage* (Gratiolet) uniting the apex of the occipital lobe with the postero-inferior angle of the quadrilateral lobule, and thus interrupting the parieto-occipital fissure. These three brains are in the Museum of Anatomy in Turin.

PANSCH in his guide commences by describing those fissures, which are the result of the bending in of the thin wall of the cerebral vesicles, which he names *total furche;* viz., the fissura Sylvii, fissura occipitalis, fissura calcarina, fissura hippocampi. He then describes the sulci, which express the foldings, not of the entire thickness of the wall of the cerebral vesicle, but only of the cortex cerebri; viz., the sulcus Rolando, parietalis (intra-parietal of Turner), frontalis (præcentralis of Ecker), temporalis (parallel fissure), olfactory, collateral, calloso-marginal, and supero-frontal. The lobes of the brain are then described and the convolutions in the different lobes. The essay is illustrated by three large plates.

HESCHL describes (37) the *anterior transverse temporal gyrus*, by which he means a convolution springing from the first temporal convolution about the middle of the lower border of the Sylvian fissure, and ending either singly or by joining the second transverse temporal gyrus. These transverse temporal gyri are situated on that surface of the temporo-sphenoidal lobe which looks upwards and inwards towards the insula. The anterior transverse temporal gyrus may be seen as early as the fifth month of fœtal life in the middle of the lower margin of the open Sylvian fossa. In (22) HESCHL treats of those convolutions which lie at the bottom of the sulci, and especially directs attention to a convolution passing across the depths of the fissure of Rolando, but not reaching the surface. In six cases, out of 1087 brains examined, he found it, however, reach the surface and form a bridge between the ascending frontal and parietal gyri. DWIGHT, in his remarks on the brain of a distinguished man (40) also found a small gyrus bridging across the fissure of Rolando and occurring on both sides. This brain weighed 53½ oz. avoir., and was that of Mr Chauncey Wright, a man of varied acquirements as a general critic, and specially proficient in physics and mathematics. M. BROCA points out (14) the necessity, in order to avoid confusion in comparing the descriptions of different writers on the anatomy of the hemispheres, of having a fixed method of nomenclature. He then proceeds to explain the nomenclature which he employs in his descriptions of the lobes, lobules, fissures, and convolutions, and to lay down a method of notation of the fissures and convolutions. ZUCKERKANDL directs attention (59) to an appearance on the surface of the gyrus hippocampi, quite distinct from the fascia dentata, which he regards as indicative of the presence of a distinct convolution, situated between the fascia dentata and the gyrus hippocampi.

b. Cranio-cerebral topography.

M. BROCA contributes (12) an important memoir on the relations of the brain to the surface of the head. He reviews the methods employed by Gratiolet, Bischoff, Heftler, Turner, Féré, and Ecker,

and points out how a knowledge of cranio-cerebral topography may be applied to medicine and anthropology. He then proceeds to discuss the practical value of the methods which have been employed, and decides in favour of the method of introducing wooden pegs, through holes bored through the skull, into the surface of the brain. This method he had employed many years ago, and communicated the first results he obtained in a memoir on the seat of the faculty of language, published in 1861. He then gives a description of the relations of the fissure of Rolando, the parieto-occipital fissure, and the fissure of Sylvius to the surface of the skull, and from a knowledge of these proceeds to show how the position of the other fissures and of the convolutions may be determined. He then relates a case where an abscess, situated in the region of the brain, associated with the faculty of speech was diagnosed, and where the pus was evacuated by trepanning the skull over the spot. M. Pozzi writes an account (35) of the cerebral convolutions and of their relations to the skull, with especial reference to the use of the trepan in cases where its employment may be deemed advisable. He gives some cases in illustration.

Ecker, in a memoir on the effects produced by distortion of the skull on the size, shape, and position of the cerebrum (23), concludes that in the "flatheads" the cranial capacity has not been diminished and the volume of the brain has not been essentially altered. In one of the chapters of this essay he describes his method of determining the relations of the brain to the skull. In (24) Ecker continues his observations on the method of determining these topographical relations.

Giacomini writes (10) a special memoir on a new method of determining in the living body the exact situation of the fissure of Rolando, and a description of its relations to the skull and to the deeper parts of the brain. The observations have been made on the strongly brachycephalic Piedmontese type, and the method is only applicable to well-formed heads. It is as follows:—Let the head rest horizontally on the vertebral column, and be accessible from all sides. Determine exactly the sagittal line, and trace it on the head with some colouring matter. By means of calipers find the points on the surface of the scalp corresponding to the greatest transverse diameter, and mark these also. They are generally a little above, and in front of, the summit of the ala of the ear. With the aid of a steel ribbon trace a curved line passing over the vertex, uniting these two points, and cutting the sagittal line at right angles. Care must be taken that the head is kept perfectly horizontal on the spine, that the limbs of the calipers fall symmetrically on the sides of the head, and that there are no folds of the scalp, due to manipulation. The plane in which this curved line lies will cut the fissures of Rolando nearly in their middle, and the points in which the lines of the fissures cross the curved line will be exactly midway between the sagittal line and the marks of the greatest transverse diameter, so that the midpoint of each lateral half of the curved line lies over a fissure. To trace the fissure now, we must know at what angle the line of the fissure crosses

the curved line—from experiment this angle oscillates between 30° and 35°. With the aid of a graduated steel ribbon mark the midpoint of the lateral half of the curve line, and through this point trace a line passing from above downwards, forwards, and outwards, and cutting the curve line at the required angle. This line is over the course of the fissure of Rolando, and may be called the "Rolandic line." In 11 female and 24 male subjects the Rolandic line was thus traced, and a tract of scalp, skull, and membranes, parallel to the line, and half the breadth of the crown of a trephine on each side of it, removed. In the majority of these the fissure ran in the middle of the tract of brain so laid bare; when it did not, it was as often before as behind the middle, but in no instance did it extend beyond the margins of the section. The method was tested also by Broca's plan of inserting pegs along the Rolandic line, and the results were equally satisfactory.

M. Bitot details (36) a method of determining cerebral topography by a mode of cerebrotomy. He places the brains in metal dishes of the shape of the brain. The sides of these dishes are traversed by a number of slits running either transversely to the long axis of the dish, and therefore of the brain contained in it, or horizontally, or antero-posteriorly. A long-bladed knife is then introduced through the slits and slices made through the brain, either vertically transversely, or horizontally, or antero-posteriorly, according to the direction of the slits in the sides of the dish into which the brain that is being examined is placed. A series of successive sections may in this manner be made, and these sections may be mounted between two plates of glass in a mixture of equal parts of alchohol and syrup. M. Bitot then appends photographs, with descriptions of a series of sections made in the vertical transverse direction through the middle region of the brain. He gives also a plate of the relations of the brain to the surface of the skull, and several wood-cuts of the instruments he employs.

M. Féré's observations (16) on the relations of the cerebrum to the surface of the skull and head, have been made with the especial object of localising surgical lesions of the brain. He has examined 54 female and 8 male heads and has used the method of pegging recommended by M. Broca.

M. Pitres has endeavoured (17) to arrive at a method of nomenclature of the different regions of the centrum ovale sufficiently precise to enable the physician to localise the regions within the hemisphere in which pathological changes may occur. He makes sections through the hemisphere parallel to the fissure of Rolando,—one 5 c.m. in front of that fissure, and another in the vicinity of the internal perpendicular (occipito-parietal) fissure. The hemisphere is then divided into a pre-frontal, a frontal-parietal, and an occipital segment. Lesions limited to the pre-frontal region do not, he says, occasion hemiplegia, and the same statement may be made of lesions of the occipital segment. The middle or fronto-parietal segment contains the strands of nerve fibres in the centrum ovale which are motor in function, what M. Charcot names the motor portion of the hemis-

phere; but this segment is divided into a lower temporo-sphenoidal, which has not any motor activity, the seat of which is to be looked for above the Sylvian fissure. He divides this motor region by four successive sections, vertical and parallel to the fissure of Rolando. The first is cut off 2 c.m. in front of the fissure of Rolando, and contains three perpendicular bundles of nerve fibres, which he names superior frontal, middle frontal, and inferior frontal. A second slice is removed by dividing in the plane of the ascending frontal convolution, and in this slice three frontal bundles, with a sphenoidal bundle of nerve fibres are seen in the centrum ovale. A third slice is in the plane of the ascending parietal convolution, whilst a fourth is sliced off 3 c.m. behind the fissure of Rolando; in each of these bundles of fibres, which may be termed superior and inferior parietal and sphenoidal may be recognized, whilst in the more anterior slice there is also a middle parietal. Cases illustrative of lesions in several of these regions are given.

c. Comparative Anatomy of Convolutions.

Adolph Pansch (1) considers that he has been able to establish the existence of corresponding regions in the cerebrum of the Primates and Carnivora. He holds that three primary fissures occur on the outer surface of the cerebrum of all animals with convoluted brains. In the Primates they lie radially above the Sylvian fissure, but in other mammals the first or most anterior is more vertical, whilst the second and third have a sagittal direction; the convexity of the first is directed forwards, that of the others upwards.

The first primary fissure is the præcental of Ecker in the primates, the anterior arched fissure (*Bogen furche*) in the dog; the second primary fissure is that of Rolando in the primates, and in the dog the anterior part of the so-named upper arched fissure; the third primary fissure is in the primates, the sulcus interparietalis (intra-parietalis) of Turner, and in the dog the anterior part of the middle arched fissure (*Bogen furche*).

The cruciate fissure (*Kreuz furche*), though important when present, does not belong to the general type, as it is absent in many carnivora. The fissure, which Hitzig has compared with that of Rolando, belongs, according to Pansch, in its lower half to the sulcus interparietalis (intra-parietalis), whilst its upper part is composed of two fissures, which do not belong to the general type, but present many variations. Not only has the fissure of Rolando its morphological equivalent in the dog's brain, but the ascending frontal and parietal convolutions have their equivalent parts in the anterior ends of the third and fourth convolutions of Leuret. Those fissures which arise first in development are deepest in the adult brain. With the exception of the oldest fissures, variations occur often to a considerable extent, more especially in the human and other brains rich in fissures. All mammals have a Sylvian fissure either well marked or rudimentary.

Pansch continues his observations on this subject in (3), and criticises amongst others the memoirs of Meynert (27) and Benedikt (25). In (2) he summarises the results of his observations, extending

over many years, on the convolutions of the cerebrum in man and mammals. The furrows and gyri are the expressions of foldings on the surface. These foldings have a definite arrangement in each species of mammal, and mammals can be arranged in smaller and larger groups according to the type of their convolutions. The earliest furrows to appear on the smooth brain of the fœtus are sharp and short, and they elongate either directly or by union with adjacent furrows. They do not all appear at the same time, and the first to appear are constant in position, whilst those which arise later are more variable. The earliest become the deepest, the later ones are more shallow. The growth of two convolutions separated by a furrow is proportional, so that a furrow, extending with vertical sides from the surface is produced, but unequal growth may occur, so that one convolution is higher than another, or an operculum may be produced. A disappearance later on of furrows or parts of furrows existing in earlier stages only seldom occurs. The furrows and their relative depths form, therefore, the first and most definite objects for description and investigation.

JULIUS KRUEG inquires (28) into the furrows of the cerebrum in the *Ungulata*. He gives an historical introduction to the subject, and then proceeds to describe his method. He next inquires into the furrows and figures them at different stages in fœtuses of the sheep, ox, and pig. He describes a *fissura rhinalis*, and a *fissura hippocampi* (dentate fissure) as appearing very early, and simultaneously with the development of the tractus olfactorius, and the hippocampus. In the earliest sheep's brain he examined (the fœtus being 19 centimetres long) he saw the first indications of a *Sylvian fissure* on the lateral surface, and of a fissure on the median surface, which he names *fissura splenialis*. The fissura splenialis lies parallel to the corpus callosum, near the upper border of the hemisphere, and he is disposed to think that it is homologous with the parieto-occipital fissure in the human brain. At the next stage (21 centimetres) three new fissures have appeared: The *fissura suprasylvia* lies above the Sylvian fissure, and subsequently elongates into anterior, posterior, and superior processes: The *fissura coronalis* is situated at the upper part of the lateral surface of the hemisphere in its anterior half, more or less parallel to the median border: the *fissura præsylvia* extends almost parallel and close to the lower half of the anterior border of the hemisphere, and often blends with the anterior process of the Sylvian fissure. In a fœtus, 70 centimetres long, the *fissura diagonalis* extends obliquely from below, upwards and forwards, on the outer surface of the hemisphere; the *fissura lateralis* appears on the same surface behind the posterior fissure and almost parallel to the inner border of the coronal fissure; the *fissura postica* extends horizontally between the hemisphere; os of the fissura suprasylvia, and the fissura rhinalis. The *fissura genualis* curves round the anterior end of the corpus callosum. The last fissure to appear is the *fissura rostralis*, situated upon the median face of the hemisphere in front of the fissura genualis; it is scarcely to be seen in the brain of the fœtus, though constant in the adult. The author also gives a description and figures of the same fissures in the fœtal brains of calves and pigs. He then describes,

either from his own observations, or from figures published by various anatomists, the fissures in the Tragulidæ, Elaphiæ, Giraffe, Cavicornia, Tylopoda, Suillidæ, Hippopotamidæ, Tapiridæ, Nasicornidæ, and Solidungula. The fissures of the cerebrum in the Ungulata are then compared with those of the Carnivora, and taking the dog's brain as the type, he recognises in it the following fissures: rhinalis, hippocampi, Silvii, splenialis, suprasylvia, coronalis, præsylvia, lateralis, whilst there are doubts if the homologues of the fissura diagonalis, postica, genualis, and rostralis, are present. He describes, more especially in the brain of the Cavicornia, a fissure by the name of *Bügel* (bow) as present at the posterior end of the fissura coronalis, which passes transversely down the outer face of the hemisphere, and in the sheep, ox, and various other ruminants, reaches, by its upper end, the inner border of the hemisphere. The *Bügel* is not homologous with the *sulcus cruciatus* in the brain of the carnivora, though in the brain of the perissodactyla there is a fissure which may, it is possible, be homologous with the sulcus cruciatus.

Paul Broca has recently published (15) an elaborate memoir on the comparative anatomy of the cerebral convolutions. This memoir is the most important contribution to the anatomy of the convolutions which has appeared in France since the publication of M. Gratiolet's classical treatise. He commences by giving an account of the well-known convolution in the human brain, described by Foville as the *circonvolution de l'ourlet*, but which it is more usual to describe as consisting of an antero-superior arc the convolution of the *corpus callosum*, and a postero-inferior arc the *convolution of the hippocampus*. As these convolutions together form the border (*limbus*) of the great opening into the hemisphere, Broca considers that the name *circonvolution limbique* is to be preferred; but, seeing that this so-called convolution forms a special region in the hemisphere, which cannot be associated with any one of the lobes of the cerebrum, as usually described, he proposes to name it *le grand lobe limbique.* He then proceeds to discuss the importance of the olfactory sense, and of the olfactory lobe in the vertebrata, and concludes that, where the olfactory lobe is well developed, the great limbic lobe is in consequence very complete. This great lobe exists, however, more or less distinct, voluminous, and complete in all mammals, and of these he selects for description the otter, as furnishing a good typical example of the lobe. He illustrates the limbic lobe in this animal by several figures, and shows the connection of the olfactory lobe with it; he points out that it is circumscribed by, and separated from, the surrounding cerebral convolutions by the *limbic fissure.* The place where the part of the lobe which belongs to the corpus callosum becomes continuous with that belonging to the hippocampus, is indicated by a bridging convolution passing across the limbic fissure, which connects the parietal posterior part of the lobe with the great limbic lobe. This bridging convolution is absolutely constant in all mammals, though it is not always superficial; M. Broca calls it *pli de passage rétrolimbique.* The lobe or convolution of the corpus callosum is in part separated from the frontal lobe by the *subfrontal fissure*, but in part is continuous with it through the *fronto-limbic* bridging convolution. Between the retro-limbic and fronto-limbic

bridging convolutions, the upper border of the convolution of the corpus callosum is separated from the convolution which bounds the great longitudinal fissure between the hemispheres by the *sub-parietal fissure.* In the otter, this fissure is prolonged, in a very oblique direction, on to the convex surface of the hemisphere, but in most carnivora, its direction on the outer surface of the hemisphere is transverse where it forms the sulcus cruciatus of Leuret. M. Broca does not regard the cruciate fissure as the homologue of the fissure of Rolando; but recognises as homologous with Rolando's fissure, one which is situated in front of the cruciate fissure and which does not reach the inner margin of the hemisphere. In the otter, as in the primates, Rolando's fissure is regarded as separating the frontal from the parietal lobe. The three convolutions in the otter's brain which lie above the Sylvian fissure, M. Broca regards as forming its parietal lobe, whilst the occipital lobe is absent. He names the small part of the hemisphere which lies between the fissure of Sylvius and the posterior part of the limbic fissure, the temporal lobule of the parietal lobe. Thus, the hemisphere of the otter consists of two distinct parts, *a*, the great limbic lobe formed by the union of the olfactory lobe, the lobe of the hippocampus and the lobe of the corpus callosum; *b*, the convolutionary mass formed of a rudimentary frontal lobe, and a large parietal lobe separated by the fissure of Rolando. M. Broca then proceeds to examine the modifications of the great limbic lobe in other mammals, and speaks in the first place of those which possess the sense of smell largely developed (*osmatic mammals*) such as the smooth-brained marmot, beaver and rabbit, and the gyrencephalous horse, two-toed sloth, fox, tapir, roe-deer, pig and dog. He then describes the arrangement in the mammals with defective smell (*anosmatic*) as the dolphin and seal. An important chapter then follows on the brain of the Primates, from which he excludes the family of the Lemurs. He summarises the characters of the brain in the primates as follows:—*a*, enormous development of the frontal lobe and consequent thrusting back with change in the direction of the fissure of Rolando; *b*, subdivision of the parietal into the proper parietal, temporal, and occipital lobes; *c*, constitution of the occipital lobe owing to the formation of the occipital fissure (parieto-occipital fissure), also increase in size of the calcarine fissure; *d*, constitution of the temporal lobe owing to the elongation of the temporal lobule, and to the partial disappearance of the inferior arc of the limbic fissure; *e*, constitution of the proper parietal lobe, owing to the production of the temporal and occipital lobes; *f*, special constitution of the insula; *g*, considerable development of the subfrontal or calloso-marginal fissure; *h*, almost complete disappearance of the sub-parietal fissure, *i.e.* of the fissure between the parietal lobule, and the convolution of the corpus callosum. At the same time the olfactory apparatus greatly diminishes in size and importance. In the brain of the primates, everything is subordinated to the predominance of the frontal lobes, which makes great modifications in the external configuration of the organ, and renders difficult the determination of the corresponding parts in the mantle of the primates and the other mammifera. M. Broca considers that the great limbic

lobe always preserves its anatomical identity and furnishes a definite basis for the comparison and classification of the convolutions which are found in the rest of the mantle.

Special memoirs on the brains of the Anthropoid apes have been written by BISCHOFF, BROCA, and PANSCH. BISCHOFF examined the brain of a Chimpanzee (18), which he found to be so much like one previously described by him in 1871 (*Sitzberichte der math. phys. Classe der München Akad.*, 4th Feb. 1871), that a detailed description was unnecessary. The brain weighed 345 grammes. On the left side he found the superior external bridging convolution superficial, whilst on the right side it passed vertically and deeply placed as the superior internal bridging convolution. On the right side the internal and external perpendicular occipital fissures were continuous and formed an operculum, but on the left side they were separated by the above bridging convolution. On both sides the internal inferior bridging convolution (*gyrus calcarinus*) separated the internal perpendicular fissure from the calcarine fissure. No part of the island of Reil was to be seen until the Sylvian fossa was opened up. The anterior limit of the Sylvian fossa, as in all the orang and chimpanzee brains he has examined was short and bounded by the simple lower frontal convolution.

BISCHOFF describes and figures (19) the brain of an Orang. The brain after immersion in spirits for two years weighed 225 grammes; on the calculation that it had lost 25 per cent. of its weight it had probably weighed with its membranes when fresh 300 grammes. As regards the arrangement of the fissures and convolutions, the brain has throughout the type of the human brain, and so generally corresponds with that of the chimpanzee's brain that it may be said the difference is not much greater than is observed in the brains of different men. He holds that the appearance of the fissure of Rolando and of the parieto-occipital fissures in the brains of the primates constitute so important a difference in the arrangement of the convolutions as to render it impossible with any certainty to compare the convolutions on the outer surface of the hemisphere with those of the lower mammals. Moreover, he states that in the development of the convolutions the human brain does not pass through the same stages as the lower mammals.

In 1876 PANSCH described and figured (6) the brain of a young Gorilla which was subsequently sent by Dr Bolau to BISCHOFF who has given (20) a new description with figures. The specimen after having been preserved for some time weighed 265 grammes, but was estimated when fresh to have weighed 331·25 grammes. Bischoff criticizes Pansch's description more especially with reference to the Sylvian fossa, the island of Reil, the sulcus præcentralis, the inferior frontal convolution, the sulcus orbitalis of Ecker or sulcus transversus + sulcus externus of WEISBACH. From a comparison of the gorilla's brain with those of the chimpanzee and orang he has found that the gorilla is undoubtedly the best provided with convolutions in all its lobes except the temporal. M. BROCA exhibited in 1876 the brain of

an adult male Gorilla to the Anthropological Society of Paris, which he had received from Dr Nègre. In (13) he gives a full description of this brain with figures, and reviews the descriptions both of Pansch and Bischoff. His general conclusion is that the brain of the gorilla, by the large size of the frontal lobe and the smallness of the occipital, approaches nearer to the type of the human brain than is the case with any other brain, but that its convolutions are more simple, less tortuous, and larger than those of the other large anthropoids. Under this head the chimpanzee is a little inferior to the orang, and the gorilla takes the third place, but there is nothing to justify the relation which Gratiolet makes between it and the cynocephali. BISCHOFF makes (21) some observations on this memoir of Broca's in which he expresses doubt if the brain described by the latter was really that of a gorilla, and inclines to the view that it was the brain of a chimpanzee. He states that in the gorilla's brain examined by him the occipital lobe was not only larger but with its convolutions better developed than either in the orang or chimpanzee. He concludes by a special criticism of Broca's description of the inferior frontal convolution. PANSCH intimates (4) that additional specimens of the brain of the gorilla have come into his possession, and that he is preparing an account of them which will appear in a work on the brain in the Anthropoid apes.

GARROD in (50) states that the brain of the Chinese water deer is very like that of *Cervus pudu* figured by Flower, differing mainly in that the hippocampal gyrus is much less conspicuous upon the superior aspect. It is much more convoluted than the brain of *Moschus moschiferus*. In (51) Garrod figures and gives a short description of the convolutions of the cerebrum of the Sumatran rhinoceros.

In (52) Garrod figures the brain of the Manatee, and gives a description of its characters, from which it appears that the surface of the cerebrum is not convoluted, although a Sylvian fissure and a hippocampal, a superior frontal and a callosal-marginal sulcus are present.

d. Minute Structure of the Brain.

H. C. MAJOR describes (30) the minute structure of the island of Reil in the healthy human adult brain. He recognises generally in the cortex cerebri six layers, and points out that the plan of arrangement of the cortical layers in the insula differs in no respect from the usual arrangement throughout the cortex. His arrangement differs from Meynert's in this, that whilst Meynert figures only one layer subjacent to the fourth, Major, following Baillarger, describes and figures two layers The cells of the third layer in the insula are generally smaller than in the vertex, but the vessels and neuroglia present no peculiarity. In the other layers the general aspect of the cells is the same as in the convolutions of the vertex. The various gyri forming the insula present similar structure, and the gyri on the left side correspond with those of the right. The mode of union of the white matter with the cortex is similar in the insula to what has been

observed in the other lobes. MAJOR has carefully studied in the *Cynocephalus porcarius* (29) the minute structure of the convolutions on the vault of the hemispheres, more especially the ascending frontal and parietal convolutions, and the tips of the occipital lobes, and compared them with the corresponding parts of the human brain. He arrives at the following conclusions. The number of layers in the cortex cerebri in the Chacma baboon corresponds exactly with that in man, and not only are the general features of these layers closely similar in man and the baboon, but the modifications in structure in the human occipital lobe as compared with the lobes in front are also found in the Cynocephalus; the general character, appearance, and relative number of the cells in the various layers is also the same in both brains. In the Chacma, however, pale cells, hazy in outline and with large nuclei, occur more commonly than in man, and in the second layer in the frontal and parietal regions of the human brain large nerve cells are more numerous than in the corresponding regions in the baboon. In man also the number of the cell processes, and consequently the extent of their connections, is greater than in the baboon, hence in man the intercellular matrix is more largely composed of fibrils than in the baboon. Except that the quantity of the white matter is greater in the human brain there is no difference to be noted in the brain of the baboon. In the present number of this *Journal* MAJOR (31) describes the minute structure of the cerebrum of the white whale (Beluga) and points out that the chief differences between the structure of its convolutions and those of the human brain consists in this: that the third layer in the human cortex is deeper and has a greater number of large nerve cells, whilst a special row of cells fringing the lower margin of this layer in Beluga is absent in man. On the other hand the fourth cortical layer in the human brain with its closely set angular nerve cells, specially distinct in the occipital lobe, is not differentiated in the brain of the Beluga.

CLARKE and LEWIS (32) enquire into the cortical lamination of the motor area of the brain. They especially select for examination the ascending frontal convolution and describe its laminæ. They prefer to adhere to Meynert's five-laminated type, rather than with Baillarger and Major to describe six layers. They assume that the fourth layer is subject to especial modification, inasmuch as it contains cells of enormous dimensions, averaging 71μ in length by 35μ in breadth, whilst occasionally cells of 126μ in length are seen. These cells are found midway down the band of angular cells, of which the fourth layer is mainly composed. This series of large cells is not a constant layer; indeed, even in extensive portions of the ascending frontal gyrus, they are wholly absent. The authors then describe the form, size, processes, and distribution of these enormous cells which they name the ganglion cells of the cortex. These cells are distributed over certain definite areas, which are remarkably constant, and the authors believe that the groups of cells are especially and exclusively a characteristic feature of the motor area as defined by Ferrier. They admit that the cells may be found in isolated positions at parts not included in the motor area, but they

have not succeeded in finding any large groups or distinct areas in the cortex, at a distance from the region of the motor centres. In a previous paper, (55) BEVAN LEWIS inquires into the accuracy of Obersteiner's observations on the existence of lymph-sacs and perivascular channels in the brain, and states that in most points his observations are strictly in comformity with those of Obersteiner. He figures lymph-sacs and channels around the nerve-cells and blood-vessels of the cortex. BEVAN LEWIS relates (33) a more complete examination of the motor area of the cortex in man, and the regions bordering on it, and compares it with the motor area in the cat, and certain regions in the brain of the sheep. Though regarding the five-laminated type as characteristic of the motor area of the cortex he admits that a six-layered formation is found extensively spread over the convolutions of the parietal and other regions. He makes frequent reference to the joint article by himself and CLARKE (32) and proceeds to show that an abrupt passage from one form of cortical lamination to the other does not take place. The ascending parietal is a transition region, and the changes from one type of lamination to the other depend almost entirely upon alterations in the elements of the third and fourth layers. He summarises in the region of transition the distinctive features of the third layer: *a.* less depth than in regions in front, greater depth than in regions behind; *b.* large pyramidal nerve cells less numerous than in frontal region, and scattered in sparse groups in the lowest stratum of the layer; *c.* increase in number of small pyramidal cells through its whole depth, which tend to aggregate into a distinct layer below, between this and the large ganglionic cells of the 4th layer. In the cat a lamination almost identical with that in man was observed. In the sheep also the five-laminated arrangement was found in a limited region which is the analogue of those which are regarded as motor in the cat and higher mammals.

RICHET in his thesis (34) analyses the observations of a number of anatomists and physiologists on the cerebral convolutions.

ARNDT in (57) discusses certain differences in the structure of the nerve fibres and nerve cells in the human brain, and in (58) describes a peculiar morbid condition in the brain and spinal cord of an insane person.

e. Development of Brain.

MIHALKOVICS contributes an elaborate memoir (45) on the development of the brain in man and the higher mammalia. An abstract of that part which concerns the development of the hemisphere vesicles has already been given by Turner in this *Journal*, January 1878, in his account of a human cerebrum imperfectly divided into two hemispheres. The memoir commences with a description of the first appearance of the nervous system in connection with the outer layer of the embryo, the formation of the neural grove, its conversion into a tube and the separation of that tube from the epiblast layer. He then proceeds to enquire into the development of that part of the tube which becomes the brain, and traces out the formation of the cerebral vesicles. The original segmentation of the cerebral part of the tube

is into three vesicles, prosencephalon, mesencephalon, epencephalon or *Hinterhirnbläschen*. The formation of a fourth cerebral vesicle is by a secondary division of the Hinterhirnbläschen, from which the *Nachhirnbläschen* or myelencephalon becomes separated. The formation of a fifth cerebral vesicle is by a budding off from the primary anterior cerebral vesicle (prosenencephalon) of a new vesicle, which forms the hemisphere vesicle. The development of the several parts of the brain out of these different vesicles is then described. HENSEN contributes (60) a few observations with some figures on the form of the body of the embryo, and on the development of the choroid plexus of the brain.

f. Malformation of the Brain.

GIACOMINI gives an account (8) of the skeleton and soft parts, including the brain of Maria Manolino, a microcephalic girl aged 17½ years. Frequent reference is made to two other microcephalic brains, —those of Bertolotti and Rubiolio—deposited in the anatomical museum of Turin, and which were partially described by Delorenzi. The internal parts of the brain have been examined, and there is a description of the state of ossification of the bones of the entire skeleton, which has been preserved. The weight of the brain is about 550 grammes, the whole body weighing 35 kilos. In all the three brains the prœcentral lobule (Ecker) is small absolutely, and also relatively to the other parts of the brain, for it is the part that has suffered the greatest degree of diminution. In the case of Manolino, Gratiolet's *lobule du pli de passage supérieur* cannot be said to exist on either side, the supramarginal convolution being reduced to an extreme simplicity—perfectly smooth and without anastomoses whatever. In this brain also a condition exists which our author believes to be now recorded for the first time, viz., a direct continuity of the parallel and parieto-occipital fissures, due to the absence of the first and second annectant gyri and of any fold uniting the angular with the middle temporal convolution. This is interesting, for Gratiolet writes, "chez les microcéphales le deuxième pli de passage entre le lobe parietal et l'occipital est toujours superficiel, ce qui est un caractère absolument propre à l'homme. . . . Ainsi au milieu de leur anéantissement les cerveaux des microcéphales présentent des caractères humains." In Manolino and Rubiolio the posterior horns of the lateral ventricles are quite awanting, and in Bertolotti only the merest rudiment is discernable on the right side; as a consequence of this the hippocampus minor is absent, although the calcarine fissure is well developed. The essay contains frequent references to the literature of microcephalism.

It may suffice merely to refer here to the memoirs by Turner (41) and Cleland (48) as they appeared originally in former numbers of this *Journal*.

g. Weight of Brain.

DANIEL WILSON contributes an essay (38), on brain weight and size in relation to the relative capacity of races. In it he reviews the

literature of this subject, and constructs a series of tables from the data furnished by various writers. His general conclusion is, that ample cerebral development is the general accompaniment of intellectual capacity alike in individuals and races. It seems by no means improbable, that certain marked distinctions in races may be traceable to a difference in the specific gravity of the brain, or of certain of its constituent portions, to the greater or less complexity of its convolutions, and to the relative characteristics of the two hemispheres. He regards the striking discrepancy between the volume of the brain and the intellectual activity of the Peruvian races has as marked an indication of a distinctive race character as anything hitherto noted in anthropology. C. CLAPHAM continues (39) his observations on the weight of the brain in the insane. Including the 716 brains considered in a former paper, he has now communicated the results of the weighing of 1200 brains, of which 701 were males, and 499 females. The average weight of the male brain was 1356 grammes; the average weight of the female brain was 1230·4 grammes; the average difference between the male and female brains was 125·5 grammes = 4·4 oz. in favour of the men. The largest male brain, in a man of 45 years, was 61 oz.; the largest female brain, in a woman of 33 years, was 56 oz. The smallest brain in a female general paralytic, 45 years of age, weighed only 29 oz. Out of 1200 brains examined, 4 weighed 60 oz. and upwards; and 45, 55 oz. and upwards, two of the latter being female.

h. Methods of Examining and Preserving the Brain.

GIACOMINI describes (11) a process for the preservation of the brain, which retains its form and colour, and leaves it firm, and yet pliable and easily handled. It may be freely exposed to the air for any length of time, and does not crack on the surface. It loses in the process only about $\frac{1}{20}$th of its volume, and this small amount is not increased on being exposed. He says it is a true preservation, not a mummification, as are so many of the processes hitherto published. The author begins his pamphlet by setting forth the extreme difficulty hitherto experienced in getting preparations, which, while they are firm and easily handled, have yet not lost their most essential characters. He passes over those processes in which, after hardening, the organs are kept in some preserving fluid, and goes on to describe briefly those in which the organs are so acted on that they may afterwards be exposed to the air without much alteration. These are the methods of Broca, Frederig modified by Daval, Oré of Bordeaux, Boudet, and of Personne, all of which give but poor results. Then he describes his own process, which consists of two stages. In the first stage the fresh organ still enveloped in its membranes is immersed in a saturated solution of zinc chloride. In this it floats with a little of its surface above the fluid; and so, while its form is not interfered with by pressure, it must be turned two or three times a day, in order that all parts may be uniformly acted on. If the subject has been dead for some time, 600 grammes of the solution may be injected through the

carotids under slight pressure, so as to give a firmness to the somewhat softish brain before its removal. After forty-eight hours the surface is hard enough to have the membranes removed. Let this be done without taking the organ out of the solution, or, if it be taken out, let it be put into water immediately, so that it may the less lose its form by pressure. After having been cleaned, let it remain in the solution till, as the hardening proceeds, it begins to sink no longer, and then remove it. At this stage it will be firm, slightly diminished in volume, the fissures a little opened, and the colour whitish, unless the membranes have been left on too long, in which case the course of the large vessels will be stained of a rusty colour from the blood pigment. Now it is immersed in alcohol of commerce for not less than ten or twelve days, but it may be for an indefinite period; here it sinks, and so must be often turned to avoid deformity by pressure on the bottom of the vessel, and it is well to renew the spirit two or three times—the oftener, the sooner the process is required to be finished. After the alcohol the consistence is greater, the size a little less, and the convolutions somewhat closer together. Now comes the second stage. Let the organ be immersed in glycerine of commerce, or with 1 per cent. of carbolic acid added. When first put in it floats with some of its upper surface above the surface of the glycerine, but, gradually becoming heavier as the alcohol evaporates, and glycerine is imbibed, it sinks deeper and deeper, till it is just level with the liquid —then it is to be taken out. In this part of the process, neither surface, colour, consistence, nor volume are altered, but it becomes heavier. A brain should gain from 150 to 200 grammes in from twenty to thirty days, according to its volume. Now set aside for several days till the surface is dry, and then cover it with several layers of gum elastic varnish, or, better still, marine glue diluted with a little alcohol. This varnish is not to prevent evaporation—the glycerine does that—but is simply as a protection against dust and injury.

ROLLESTON'S plan of preserving the brain by the use of zinc chloride and spirit is described in the present number of this *Journal* (44).

HAMILTON'S process for preparing large sections of the nervous centres for microscopic examination has already been described in this *Journal* (54).

WELCKER shows (53) the advantages to be derived in the way of obtaining a knowledge of the ventricles of the brain by taking a wax cast of the interior of these cavities. He injects the wax into the ventricles through the infundibulum. BEVAN LEWIS points out (56) the advantage of employing the freezing microtome described by him in this *Journal*, April 1877, in the microscopic examination of the brain. He describes the form of knife he uses and his method of staining and mounting the sections.

i. *Anatomy of the Brain in Fishes.*

BURT G. WILDER exhibited (47) specimens and drawings of the brains of *Myxine*, *Bdellostoma*, *Petromyzon*, *Mustelas*, *Acanthias*, *Carcharias*, *Chimæra*, *Amia*, *Lepidosteus Salmo*, *Megalops*, and *Meno-*

branchas, and called attention to several points in their anatomy. In (48) he gives a special account of the brain of *Chimæra monstrosa*. He gives an historical summary of the literature, and points out how difficult it has become to determine the homologies of the brain in fishes since Gegenbaur has accepted Miklucho-Maclay's interpretation of the parts commonly called cerebellum and optic lobes. He describes the spinal cord, medulla oblongata, cerebellum, optic lobes, olfactory lobes, and hemispheres. The thalamencephalon is distinguished by its extreme length, and in *Chimæra* the thalami form three distinct regions — basi-thalamus, meso-thalamus, and pro-thalamus. He considers that the recognition of the distinction between a hemisphere and a pro-thalamus is the first and most essential step in the determination of the homology of the parts in front of the optic lobes.

Ehlers describes (61) the epiphysis in the brain of the Plagiostoma.

Gustavus Fritsch's memoir (46) contains a very good account of the anatomy of the brain of fishes, great prominence being given to questions of homology. In the first part the methods of inquiry are shortly given. The author recommends the brain to be placed in 80 per cent. alcohol, to which iodine has been added, till the solution has a light Madeira colour. The solution is changed the second day. The third day the brain is placed in a solution of bichromate of potassium, to which two parts of water have been added. The strength of the solution is gradually increased, until (if necessary) a concentrated solution is used. Four to six weeks sufficed for the hardening. Photographs of sections were used as the groundwork for many of the plates. The second and third parts treat respectively of the macroscopic and microscopic structure of the brain. We propose to notice some of the more important conclusions to which Fritsch's researches have led him.

Taking the parts of the brain from before backwards, there is little doubt that the first is the olfactory bulb. The second is the so-called "hemisphere." It is developed from the secondary fore-brain. It is representative of the frontal portion of the brain of higher animals, but in fishes is only equivalent to the olfactory lobe, no frontal lobe being developed. The third great sub-division is composed of the lobus centralis and the corpora quadrigemina, which are fused together. The former is developed from the primary fore-brain and from that part of the first cerebral vesicle which forms the tween-brain of higher animals. In fishes there is no marked distinction between primary fore-brain and tween-brain. It is homologous with the island of Reil and with portions of the gyrus fornicatus and gyrus uncinatus of mammals; in other words, with the "stammhirn," as distinguished from the "hirnmantel," the latter being made up of the parietal, occipital, and temporo-sphenoidal lobes, and being scarcely represented at all in the brain of fishes. The corpora quadrigemina are almost completely over-arched by the lobus centralis. They are arranged in two pairs—a postero-external and an antero-internal. They are pressed out from the middle line by the enormously developed valvula cerebelli; externally they are bounded by a kidney-shaped ganglionic

mass—the optic thalamus. Gottsche is the only author who takes notice of this ganglion; he recognised in it the Schleife or Lemniscus. The fourth sub-division corresponds with the vermiform process of mammals, but lateral appendages are sometimes present (the so-called fimbriæ and lobi nervi trigemini), and these represent the cerebellar hemispheres of higher animals. The fifth sub-division is the medulla. Fritsch discusses at length the views that different authors have taken of the homologies of these various parts.

It is pointed out that the hemispheres which, according to many authors, represent of themselves the whole hemispheres of mammals are remarkably simple in structure, whereas the "optic lobes," peripherally as well as centrally, are exceedingly complex; although they are supposed to represent the relatively simple corpora quadrigemina of mammals. Peripherally, the structure of the hemispheres is chiefly cellular; centrally, chiefly fibrous; anteriorly, the external olfactory root marks the limit between central and peripheral parts. Fritsch points out that histology, as well as morphology, indicates that the tectum opticum, or lateral part of the lobus centralis, is homologous with the cortex cerebri. He confirms Stieda's description of it, as made up of eight layers, differing only as regards the seventh layer. Stieda, however, regards it as part of the corpora quadrigemina. Compared with the cortex cerebri of mammals, it contains proportionally few ganglion cells. The large pyramidal cells that are found in the cortex of mammals have no equivalent in fishes, but cells which remind us of them are found limited to the basal portion of the tectum. To this collection of cells Fritsch gives the name of nucleus corticalis, comparing it with the claustrum of higher animals. He distinguishes ganglionic masses homologous with the optic thalamus and the lenticular nucleus, but has been unable to discover any ganglion comparable with the corpus striatum. The lobi inferiores, notwithstanding their large size, are the homologues of the corpora mammillaria. The form and position of the two organs agree, and, just as in mammals, the descending crus of the anterior pillar of the fornix passes to the corpora mammillaria, and thence, by the ascending crus, to the optic thalamus; so in Teleostei, fibres leave the torus longitudinalis (fornix) anteriorly to go to the lobi inferiores, and thence to the optic thalamus. The commissura interlobularis and the comanterior, which unite the hemispheres and the tecta optica respectively, though quite distinct from one another, are regarded as the homologues of the anterior and posterior limbs of the anterior commissure of mammals. The commissura posterior is pointed out, and also a band of commissural fibres, which answers to the *Corpus Callosum.*

The loop of the lenticular nucleus (Meynert) is represented by fibres which arise anteriorly in a group of ganglion cells in the lobus centralis, arch horizontally backwards to the middle line, decussate with the corresponding fibres of the opposite side between the substantia perforata posterior and the nuclei of the third nerves, and afterwards become associated with the posterior longitudinal fasciculus. The pineal gland and the ganglion habenulæ are situated more anteriorly than the same structures in mammals; in fishes as in

amphibians, the former forms the boundary between secondary fore-brain and tween-brain, between hemispheres and lobuscentralis. In the Teleostei there are strands composed of gelatinous substance, which are very perfect and striking, and indications of which are found in higher animals, and in man. They are in direct communication with the pineal gland.

As regards the central origin of the motor nerves, the general rule is for incomplete decussation, the greater part of the nerve remaining uncrossed. So far as investigations have gone, the only exceptions to this rule are the fourth nerve which completely decussates, and the sixth nerve which remains quite uncrossed. Decussations of sensory nerves are also observed, but they are so difficult to follow that no general principle can be laid down; incomplete decussation, however, seems to be the rule. The external olfactory root can be traced into the hinder half of the hemisphere; the internal root in part loses itself in the central portion of the hemisphere, in part decussates with the corresponding fibres of the opposite side in the *commissura interlobularis* or *anterior*. Meynert, it will be remembered, describes a decussation of the olfactory nerves in the anterior commissure of mammals. The roots of the optic tract have a very complicated course. The antero-superior root is distributed to organs evolved from the tween-brain, the postero-inferior to organs evolved from the mid-brain. The former contains imbedded in it a ganglionic mass which answers to the corpus geniculatum externum; thence fibres pass to the optic thalamus and the inner fibrous layer of the tectum opticum. The latter is distributed to a ganglion homologous with the anterior tubercles of the corpora quadrigemina.

An interesting account is given of the lobi electrici. Morphologically there is reason to regard these organs as modified lobi vagales, and Fritsch endeavours to support this view by an appeal to histology. The lateral portion of the nucleus of the vagus, consisting of small ganglion cells, imbedded in a close matrix, is in connection with the posterior root of the nerve; the median, and somewhat deeper portion of the nucleus, consisting of larger cells in a looser matrix, is in connection with the anterior root. The former may be looked on as the sensory, the latter as the motor, nucleus. Now Babuchin's observations have shown that the electrical organs of the torpedo are modified motor organs. We might therefore expect that their nerves would arise in a modified motor centre. And, in point of fact, Fritsch's researches have convinced him that the electrical lobes are evolved from a portion of the median or motor nucleus of the vagus. As Schultze and others have pointed out, the lobes contain large ganglionic cells whose characters ally them to motor cells, and intermediate forms are found connecting them with the ordinary multipolar cells. The position of the nervi electrici to the inner side of the lateral or sensory nucleus of the vagus is also in favour of the view advanced. Fritsch describes carefully the mode of growth of the lobes.

The author then describes the distribution of different kinds of fibres. The distribution of the broad fibres that stain deeply and have

the character of axis-cylinders is limited to the parts behind the hemispheres. The broadest fibres belong in general to the motor roots; the fibres of the sensory roots are as a rule finer and more closely aggregated. but there are exceptions to this rule, *e.g.*, the peculiarly broad fibres of the auditory nerve. The commissural and association fibres, and the first link of the projection system (Meynert) are easily distinguished from the fibres of the nerve roots; they are of small calibre, are closely aggregated, and stain badly. Fritsch recognises no fundamental distinction between the basal ganglia and the ganglionic centres of the medulla oblongata and spinal cord, and agrees with Forel, Flechsig, and others, that it is impossible to recognise as a definite system Meynert's second link of the projection system, consisting as it does of fibres passing from basal ganglia to the ganglia of medulla and spinal cord. Broad axis-cylinders are characteristic of the nerves of the third link of the projection system; in other words, of the peripheral nerves and their central terminations. Where fibres of this kind are found in the cerebro-spinal ganglia, they are to be regarded as the direct continuations of peripheral fibres; where they are found crossing the raphe they are to be looked on as decussations of peripheral fibres. Nowhere are there commissural fibres which have the character of broad axis-cylinders. By the intervention of ganglion cells, the fibres lose in thickness ere they advance centrally. Thus, in the case of the bipolar cells of the roots of the trigeminus, the peripheral process is about twice the breadth of the central process. The same holds probably of multipolar ganglion cells; the fine centrally directed processes correspond with the broad axis-cylinder process entering from the periphery. According to this view the broad fibres are peripheral fibres which have entered the central organs without the intervention of ganglion cells. They reach different heights; some first terminate in cells in the lobus centralis.

ROHON'S memoir on *The Central Nervous System of the Selachia* (49), which is dedicated to Professor Claus, gives the results of an investigation conducted in the Zoological Institute of the University of Vienna. It is illustrated by sixty-four drawings, and contains full notices of the bibliography of the subject. The material for examination consisted of the brains of thirteen different genera. The author concludes that the brains of the Selachia are chiefly distinguished from those of the Mammalia by a reduction in the ganglionic masses and in the fibres connected with them, and by the different lie and arrangement of equivalent parts. The following is a more particular summary of the conclusions arrived at:—

1. The first division of the brain is the fore-brain. It corresponds to the anterior part of the cerebral hemispheres of the higher vertebrata. In it are transverse fibres representing the anterior commissure, and two systems of longitudinal fibres representing respectively the pedunculus cerebri, and the posterior longitudinal fasciculus of the tegmentum. It will be remembered that Meynert describes this fasciculus as ending anteriorly in a ganglion which is in direct connection with the cortex of the operculum. On this fact Rohon bases one of his arguments for the view of the homology of the fore-brain just

given. The caudate and lenticular nuclei, the substantia nigra, and the anterior parts of the optic thalamus, together with the fibres of the crus that arise from them, are awanting. There is no trace of a tegmentum. The fore-brain contains two types of cell-elements, (1) small nuclei and (2) large cells of spindle form, that are perhaps comparable with the pyramidal cells found in the cornu ammonis and cerebral cortex of man.

2. The second division is the tween- and mid-brain conjointly. The dorsal part of the tween-brain is the homologue of the pulvinar and corpora geniculata of the higher vertebrates. The ventral part consists of the infundibulum and lobi inferiores. Between the two, and pressing forwards from behind is the mid-brain. This last is greatly developed, and answers to the corpora quadrigemina of Mammalia.

3. The third division is the hind-brain or cerebellum. The processus e cerebello ad pontem is rudimentary. The pons is wanting. A commissure connects the two halves of the hind-brain.

4. The fourth division is the after-brain, or medulla oblongata. The anterior pyramids and the nerve-nuclei on the floor of the fourth ventricle, with the exception of the nucleus for the vagus, are absent; but as morphologically new formations, we have the fasciculus longitudinalis lateralis and the columna cellularum. The former probably represents the fasciculus in man, that arises in the occipital lobe, runs in the outer part of the pedunculus, and ultimately passes to the posterior column of the cord. The column of nerve cells is perhaps the lower developmental stage of the nerve-nuclei, the higher stage being attained in vertebrates by the breaking up of the column into separate nerve-nuclei. The raphe is well developed.

5. The anterior column of the cord contains only the posterior longitudinal fasciculus; the lateral column is made up of the reduced pedunculus cerebri and a small fasciculus from the cerebellum (the equivalent of the restiform body of man); and the posterior column of the pedunculus cerebelli, the fasciculus longitudinalis lateralis, and the ascending root of the fifth nerve, with the substantia gelatinosa of Rolando. The column of nerve cells described above is continued from the medulla into the cord. Anterior and posterior *cornua* in the strict acceptation of the words do not exist.

6. The electrical lobes are to be regarded as motor centres.

7. The optic nerves can be traced to the dorsal part of the tween-brain, and to the fore-brain by way of the transverse commissure of Haller. There is complete decussation of the nerves.

8. The oculo-motor roots can be traced to the grey matter forming the floor of the Sylvian aqueduct.

9. The trochlear nerves arise, not from the grey substance of the Sylvian aqueduct, but from the equivalent of the valvula cerebelli and frenulum of higher vertebrates. Whether they decussate or not it is difficult to decide from direct observation, but other considerations incline Rohon to agree with V. der Kolk that they do not.

10. The first or ophthalmic branches of the fifth nerves pass to the lobi trigemini, and thence to the cerebellum. The roots of the second

and third branches of the fifth, and the facial and auditory nerves are not distinguishable from one another as independent strands; they form what Gegenbaur calls the "trigeminus group" of fibres. They spring from the raphe, the floor of the fourth ventricle, the cerebellum, and probably also from the cell-columns of the medulla.

11. The sixth nerves are connected with the cell-columns on the floor of the fourth ventricle.

12. The glosso-pharyngeal nerves arise from the raphe and from the grey substance on the floor of the fourth ventricle.

13. The nuclei of the vagi do not belong to the grey matter of the fourth ventricle, but are distinct formations. They, therefore, do not correspond to the nuclei of the vagi and accessorii in man.

14. The inferior roots of the vagus (Gegenbaur) correspond to the hypo-glossal nerves of higher animals.

15. In the *Hexanchus griseus* the nervus recurrens or accessorius of Willis is well seen.

Notices of New Books.

ELEMENTS OF HUMAN PHYSIOLOGY. By L. HERMANN. Translated and Edited by ARTHUR GAMGEE, M.D., F.R.S. London, 1878.

IN preparing a second edition of his translation of Hermann's well-known text book on Physiology, Professor Gamgee has retranslated many sections of the work from the last German edition, in which the author had materially altered, and indeed in some parts entirely recast the work. Dr Gamgee has also supplemented the text by the addition of new matter, which, except in the sections on animal chemistry, where the alterations and additions have been too numerous to render the plan practicable, is distinguished from the author's text by being enclosed in brackets [ ]. The editor has also introduced a summary of the anatomical distribution of each cranial nerve, illustrated by a number of artistically executed diagrams prepared by Mr Alfred H. Young, M.B. of the Owens College. The value of the work has by these various additions been materially increased, and the editor may be congratulated upon the part which he has performed in providing the student of physiology with so valuable a text-book.

THE CROONIAN LECTURES ON CERTAIN POINTS CONNECTED WITH DIABETES. By F. W. Pavy, M.D., F.R.S. London, 1878.

In these lectures, which have been collected into an octavo volume of 126 pages, Dr Pavy defends his well-known observations on the relations of the blood and liver to sugar, from the criticisms to which they have recently been subjected by M. Claude Bernard and some of his pupils. He maintains that he has established by quantitative analysis that there is only a small amount of sugar naturally existing in the blood. Corresponding with this small amount of sugar in the blood, there is something under 0·5 per 1000 normally present in the urine. No material difference exists between the amount of sugar existing in arterial and venous blood, and consequently in proportion to the ingress of sugar into the circulatory system, whether from the food or the liver, there must be removal by destruction or otherwise, to obviate increasing accumulation. The urine is the channel by which elimination of the sugar takes place, and whatever accumulation of sugar in the system occurs, becomes revealed by the condition of the urine. The liver, again, is not a sugar-forming, but a sugar-assimilating organ, and its great function in relation to sugar is to prevent this principle reaching the circulation to any material extent, so that the urine contains in its normal state scarcely an appreciable quantity of sugar; but when the assimilative action of the liver is not properly exerted, then sugar passes into the blood and is excreted by the urine, which consequently possesses a marked saccharine or diabetic character. The sugar derived either directly or indirectly from the food, and absorbed by the portal vessels, is, in the healthy state of the body, stopped by the selective action of the secreting cells of the liver, and by them transformed into amyloid substance. The author then proceeds to discuss the conditions under which a diabetic state of the urine may be produced. The work is an interesting and lucid statement of the author's views on the subject of diabetes.

Journal of Anatomy and Physiology.

CASE OF OBLITERATION OF VENA CAVA INFERIOR, WITH GREAT STENOSIS OF ORIFICES OF HEPATIC VEINS. By WILLIAM OSLER, M.D., M.R.C.P., *Professor of the Institutes of Medicine in M'Gill University, Montreal.* (PLATE XVII.)

THE causes of obliteration of the inferior vena cava in the great majority of cases have been either compression or the extension of thrombi from other veins. A few cases are on record in which the closures could not be referred to either of these causes, and have led some authors to conclude that the vena cava may be the seat of a primitive phlebitis. The occlusion, also, in the majority of instances has affected the vessel below the entrance of the hepatic veins, the cases of Baillie[1] and Reynaud[2] being the only ones in which these are reported to have been involved.

The following case bears, in an interesting manner, upon both these points, inasmuch as the obliteration can neither be traced to compression nor to the extension of a thrombus, and had probably lasted some years, the vein being converted into a firm fibrous cord; and the hepatic veins, where they enter the cava, are so far involved as to be reduced to the condition of insignificant orifices. In addition, the case presents features of anatomical and clinical interest.

For the following clinical notes I am indebted to Dr Johnson Alloway, of this city, under whose care the patient was during his last illness :—

[1] Quoted by Hallett, *Edinburgh Med. and Surg. Journal*, vol. lxix. 1848.

[2] Quoted by Hallett, *l. c.;* and Peacock, *Medico-Chirurgical Transactions*, vol. xxviii.

History.—J. G., æt. 24. "Mother died of cholera, father of ague. Brothers and sisters (two of each sex) strong and well. Has never been a very strong man, always pale and anæmic. When a child, was backward in his nutrition, and always considered the delicate member of the family. Was originally a carpenter by trade, but for the past three years has been employed as a packer in a warehouse, a position where he had a good deal of hard work. Has never had syphilis. The only serious illness of which there is any record is an attack of pleurisy about thirteen years ago, which very nearly proved fatal; side not known. Has suffered from piles. For some years past his legs have been more or less swollen, but he could not say exactly for how long, nor had he suffered any seriou[s in]convenience. During the past three years I have attende[d him] at intervals for dyspepsia and diarrhœa, and once for a s[evere] attack of facial neuralgia.

On December 12th, 1878, he came to me complaining of diarrhœa and intense pain in the lower bowel during passage of stools. On examining rectum, mucous membrane much congested and veins enlarged. Two weeks ago, when running up stairs, a varicose vein burst in one leg, and since then he has worn an elastic stocking. For nine days he was confined to the house with symptoms of gastric and intestinal catarrh, only occasional vomiting; once or twice a little blood was noticed—never any blood in the stools. On the 21st (Saturday) he was so much better, that I told him he might go to work on Monday. He was, however, not so well on the following day, and I was sent for, but could not go. On Monday I found that he had had a return of the symptoms, and he complained of his belly being swollen. On examining him (it was for the first time), I found a small amount of fluid in the flanks, the legs were a good deal swollen and pitted as high as the hips, the œdema extending round to the lumbar region. During the next few days the ascites increased rapidly. A distinct *bruit* was heard over the heart, and is described in a note below [1] by Dr Howard,

[1] "A loud presystolic murmur exists over a large area, of maximum intensity, in the lower sternal region, near xiphoid cartilage; it is very distinct just inside of left nipple, and faintly audible in left lateral region, and distinctly audible in left vertebral groove, opposite the xiphoid cartilage. The murmur is not audible at the base of the heart where the cardiac sounds are normal. Apex beat at nipple

who saw the patient in consultation with me. At this time he had the appearance of a man suffering from cardiac dropsy. By the 28th the abdomen measured 41 inches round the umbilicus, and to give relief, paracentesis was performed, and about eight quarts of serum removed, of a greenish hue. The urine during the early part of the illness was diminished in amount, not more than 8 to 10 oz. in the twenty-four hours, but afterwards the quantity rose to about 30 oz. daily. On four separate occasions it was tested for albumen, but none was discovered. The diarrhœa had ceased, but he occasionally vomited. On January 6th, nine days after the first tapping, the fluid had reaccumulated—measurement at umbilicus, 42 inches. Veins of abdomen ...nctly marked, and could be traced like rivers on a map; ...ling of the legs not so great. He was again tapped, and ...r ten quarts of fluid removed. After the operation the THI ...rgin of the liver could be felt—it was extremely hard. He complained of no special pain during the illness, only of the distress caused by the fluid. Deep pressure over the pancreas was painful, and it was thought that a hard mass could be felt in this situation. The fluid quickly reaccumulated. On the 12th, there was considerable pain over the distended abdomen; symptoms of collapse supervened, and it was thought that peritonitis had set in. The heart's action gradually failed, and he died on the 15th. The swelling of the legs had diminished greatly during the last days of his illness. After death, for the convenience of the friends, the belly was tapped, and about eight quarts of slightly turbid fluid removed."

Autopsy, twenty-five hours after death. Body that of a man rather under the average size. Very little fat, but not emaciated. Skin of upper part of thorax and in dependent regions livid from *post-mortem* discoloration. Belly is flat and flaccid, about two gallons of fluid having been removed after death. Legs moderately swollen; veins distinct and prominent, but not remarkably enlarged—some are varicose. Scrotum and penis slightly swollen. Superficial veins of abdomen enlarged to a

line, rhythm and impulse normal. Jugulars neither distended nor pulsating. While quite puzzled as to the source and cause of the murmur, I supposed it to be due to mitral valve disease. No murmur existed along the abdominal aorta." Dr Alloway states that after the tapping the murmur diminished or entirely disappeared.

moderate degree—scarcely so evident, perhaps, as they were during life, according to the description of the medical attendant.

Abdomen.—Entire peritoneum of an intensely livid red colour, from injection of capillaries and veins. ℥xxx of turbid, brown-coloured fluid remain in the flanks, and a few flakes of lymph float in it. The general surface is, however, smooth and glistening—not rough and dimmed, as in peritonitis. The walls of the intestines are relaxed, sodden, and heavy, and the mesentery is also very thick.

Thorax.—No fluid in pleuræ; a few adhesions at right apex.

Heart, of average size. All the chambers contain coagula; those in the ventricles colourless, firm, closely interlaced with columnæ carneæ, and extend into the arteries. Right auricle distended with a firm gelatinous clot, which extends into both cavæ. Auriculo-ventricular orifices not dilated; all the valves healthy. Muscle substance of good colour. Aorta normal—no atheroma.

Lungs, crepitant throughout; collapsed at bases, otherwise healthy.

Spleen, double the normal size, very firm, and cuts with great resistance. Capsule not thickened. Pulp dense, trabeculæ and vessels prominent.

Kidneys are large, exceedingly dense and hard to the touch. Capsules peel off with difficulty, portions remaining on the organs. On section, vessels of both cortices and medullæ very full, and the veins about bases of pyramids remarkably large.

Ureters and bladder natural.

Pancreas is unusually dense and firm (so much so, that when first examined it was thought to be the seat of scirrhus). On section, the induration is found to be due to the great increase of fibrous-tissue about the acini.

Liver is increased somewhat in size, feels heavier than natural, and is very hard and firm to the touch. Surface is not perfectly smooth, but is mapped out into irregular slightly-projecting areas, which are most distinct towards the anterior border. The capsule is not thickened, nor are there any cicatrices. About the anterior half of the organ, on both surfaces, the capsule is studded over with innumerable small, semi-opaque bodies, ranging in size from a grain of sand to a millet-seed.

They are little fibrous outgrowths from the capsule, and presented a remarkable appearance on the dark brown surface of the organ. The substance cuts with resistance, and the lobules are seen to be very distinctly marked, of good colour, not fatty, and the central veins in many unusually prominent. There is considerable excess of fibrous tissue in the organ, chiefly about individual lobules and along the course of the portal canals. A striking feature on the section is the number and size of the hepatic veins.

Gall-bladder is full of bile; ducts natural, common bile-duct large and patent.

Stomach large, and contains the remains of food, together with a thick, dark-coloured mucus. The whole lining membrane is of a deep red colour, about the cardia almost black, from the overfilled capillaries and veins. In the pyloric region there are several large areas of a dark slate-grey colour, and ten to twelve small superficial erosions, with dark bases. The membrane appears of average thickness. Sub-mucous veins are enlarged and prominent, particularly on the lesser curve and about the cardia.

Small Intestines very dark in colour; walls relaxed and sodden, but the serous coat is smooth. Mucosa is uniformly dark and congested.

Large Intestines contain a small quantity of fæces; walls are dark, mucous membrane congested. Numerous large veins about the *caput cæci* and along the sigmoid flexure and rectum.

Mesentery is heavy and coarse-looking. Peritoneum smooth, not so dark as over bowels. On section, veins large; fat everywhere traversed by small vessels, and the lobules much more distinct than usual. The glands are dark in colour, but not apparently enlarged.

Venous System.[1]—Superficial veins of abdomen and thorax not specially prominent, not nearly so much so as in many cases of cirrhosis. Veins of the legs enlarged, a few varicose, but here also the distension was by no means remarkable.

[1] The unfavourable circumstances under which the *post-mortem* was performed did not permit of so thorough an examination of the veins as might have been desired, nor was it until towards the close of the inspection that the nature of the lesion was suspected. The parts from which the sketch was taken were removed and subsequently dissected.

Vena Cava inf.—From the right auricle to the diaphragm natural-looking, and filled with a large consistent clot. Orifice looks of normal size. *Intima* is clear, and the other coats are not thickened. At the diaphragm this portion of the vein terminates in a sort of *cul-de-sac*, the floor of which is made up of cicatricial tissue, and on either side two small orifices open into it—the hepatic veins. From this point to the entrance of the left renal the vein is represented by a dense fibrous cord, 62 mm. in length, narrow at the middle (10 mm.), wider at either end, just above the renal measuring 18 mm. The central part of the cord lies between the lobus Spigelii and right lobe, and has tolerably firm adhesions to the liver substance, while at either end the connections are not so close. On section it presents a dense, fibrous aspect, with a peculiar greyish translucency, and no trace of blood-colouring matter. It is solid throughout, and apparently composed of bundles of connective-tissue. A tiny vein penetrates it from below for the distance of 12 mm. The surface of the right lobe in the neighbourhood is rough and thickened, but not more so than is usual at the site of attachment to the diaphragm; the tissue of the lobus Spigelii is perfectly natural-looking, even to the very margin of the cord. The obliteration terminates at the left renal, and below this the cava measures 40 mm., and then gradually widens to the bifurcation, above which it measures 70 mm. in circumference. The vessel is opaque, the walls three or four times the normal thickness, and externally marked by a longitudinal striation, which is specially distinct at the upper part. The *intima* is thickened and rough, and above presents one small calcareous plate; in the middle portion elevated lines run in different directions, giving a reticulated appearance to the membrane, while at the bifurcation there are several sharply-circumscribed atheromatous swellings. The vessel presented the following branches:—

Left Renal, which forms a large trunk, 30 mm. in circumference, with thick, opaque walls. It enters the cava somewhat obliquely.

A vessel, nearly as large as itself, enters at the posterior superior border, but, unfortunately, its further course was not traced. A second still larger branch enters from below, at right angles, and is described hereafter.

Right Renal, not so large as the left, enters the cava nearly at the same level.

Right Spermatic, forming a large branch, 22 mm. in circumference, which empties a little below right renal.

Lumbar, consisting of three or four greatly dilated vessels. Only three orifices were found in the posterior wall of the cava, but the veins on either side may have united, as is not infrequently the case. These branches as they pass out over the vertebræ are remarkably large; the little finger could be readily inserted for some distance into them.

Iliacs, considerably dilated, the left branches rather more than the right.

A large vein, almost equalling in size the vena cava (measuring 32 mm.), extends along the left side of the aorta from the renal to the iliacs. Above, it enters the left renal just before that vessel crosses the aorta, below, it divides into two branches, one of which, the smaller, somewhat horizontally placed, enters the left common iliac, just below the bifurcation of the cava, the other passes down for a short distance and opens into the external iliac. Posteriorly, this vessel receives four moderate-sized veins.

Pelvic Veins are all enlarged and prominent, particularly those about the rectum—hæmorrhoidal plexus.

Diaphragmatic Veins very much distended, forming a close network with the veins in the coronary and lateral ligaments of the liver, and also with those of the lesser curve of the stomach.

Œsophageal Veins form a close plexus, which receives many large veins from the cardiac end of the stomach, all the loose connective-tissue about the mediastinum above the diaphragm is exceedingly rich in venous branches.

Azygos Major is immensely distended, equalling the vena cava inf. in size, measuring about the centre of its course 62 mm. in circumference. The walls are very thin, but healthy, and the diameter increases a little near the sup. cava, into which it opens by a large orifice, admitting readily the index finger. The intercostal veins, particularly the lower ones, are very much enlarged.

Azygos Minor is also large, but not more than one-fourth the size of the azygos major, into which it empties at the usual site Unfortunately, its connections with the lumbars could not be traced.

Int. Mammary Veins are moderately enlarged.

Vena cava sup. and its branches—so far as they were traced—present nothing unusual. It did not appear much dilated where it enters the auricle.

Portal System.—Mesenteric vein and all its branches are distended with blood, even to the smallest vessels. Splenic vein also large. Portal vein measures 33 mm. in circumference, right branch admits the little finger, walls healthy. Branches in the liver do not appear much dilated.

Hepatic Veins.—In many of the lobules the *venæ centrales* are distended, and one of the most striking features on the cut section is the number and prominence of the hepatic veins of all sizes. Two main branches, one in each lobe, pass obliquely towards the cava, enlarging greatly in their course, and finally open by the two small orifices already referred to. Immediately behind the openings the veins are much dilated, but the walls are thin and not atheromatous. The right orifice measures 9 mm. in circumference, and its margins are formed by fresh-looking connective-tissue, which at the posterior part forms a sort of imperfect valve. The opening of the left vein is smaller, 7 mm., and situated at the bottom of a small funnel-shaped depression of the cava.

Microscopical Examination.

Obliterated Vein.—Transverse sections of the fibrous cord show (1), an external zone, 3 mm. in width, separated from the central part by a well-marked line of elastic tissue. This, apparently, represents the vein wall, and is made up of fibrous and elastic tissue, the former in coarse bundles, often enclosing irregular areas, which appear to contain transversely-cut muscle bundles; the latter in fine fibres, running in different directions and forming at the inner part a dense interlacement. (2) The central portion, composed of closely-compressed bundles of connective-tissue, which even in thin sections, do not present any evident structure, but are homogeneous, staining deeply and uniformly in carmine. In places it is more loosely arranged and distinct, fine fibrils can be seen, often interspersed with fine colourless granules. No crystals or melanin grains, nor are there any traces of an old blood-clot. The cut ends of a few small vessels are seen on the sections.

Liver.—Sections under a low power have a very porous appearance from the number of enlarged veins of all sizes up to half a millimetre. The majority of these are branches of the hepatic vein, but some with thick walls are portal. The intralobular veins do not appear so much enlarged, proportionately, as the larger branches. Narrow zones of fibrous tissue surround the lobules, in places broad bands are seen. The degree of cirrhosis is not appreciated until thin sections are examined, when it is seen that the connective-tissue within the lobules is very much increased, extending between the columns of cells and surrounding small groups or even isolated cells. It did not seem more advanced in the central parts of the lobules than at the periphery. The liver cells are granular, not fatty, but in many places compressed and atrophied. In the vicinity of the larger vessels they contain pigment. The spaces between the cords of liver cells appear large, but not to the same degree as in many cases of red atrophy of this organ.

Kidneys.—Interstitial tissue between the tubules much increased in thickness. Renal epithelium a little more granular than normal, but not fatty. Tubules in cortex not swollen or obstructed. The condition of the Malpighian bodies is the most striking feature in the sections, fully one-half of them being atrophied. The healthy ones are large, capsules somewhat thickened, capillary tufts prominent, and individual loops dilated. The atrophic ones are not one-third the size of the others, stain deeply in carmine, and are surrounded by a very thick fibrous sheath, with the fibres concentrically arranged. The central tuft is reduced to a granular or homogeneous body, often containing oil drops. They can be seen in all stages of degeneration. The small arteries are thickened, particularly in the middle coat.

Pancreas.—The excessive induration is due to an unusual amount of fibrous tissue between the acini; the cells do not appear atrophied.

Remarks.—The question naturally arises in reading the report of this case, Could the obliteration have been congenital? The absence in the history of any acute illness which may be supposed to correspond to the date of occlusion, and the general backwardness of nutrition, favour such a view, but there is nothing else

to support it. Whatever may have been the primary cause of the obliteration, it must have led to the formation of a thrombus, the final transformation of which is represented by the cord-like structure described above. In the absence of any source of compression, or of any pathological state in the branches, we are driven to the conclusion that the initial changes have been local, and confined to the part of the vessel affected. It is difficult, however, to conceive of a localised phlebitis in a trunk like the inferior cava, and still more of an acute process, the effects of which would have been limited to the short distance found occluded. A chronic obliterating endophlebitis is not, so far as I know, recognised. In the remarkable case reported by A. Robin,[1] the first symptoms followed violent and prolonged exertion, being ushered in with "fever, delirium, increase in size of abdomen, with violent lumbar and abdominal pain." There is no history, in the case under consideration, of any severe illness except pleurisy, during which, so far as can be ascertained, there was no dropsy. The only possible connection with this attack might have been copious right-sided exudation, with great dislocation of the heart, when the inferior cava might have got a twist (Birch-Hirschfeld).

From the state of the vein at the site of the obliteration we can infer that the obstruction has been of some duration, but how long it is impossible to conjecture, for such a dense, fibrous cord, when once formed, might remain unaltered for years. The atheromatous and thickened state of the cava below the renals must be regarded simply as an expression of the strain to which this part of the vein had been subjected. The great increase in the connective-tissue of the liver and other organs is what might have been expected, and is in itself evidence of the long-standing nature of the obliteration.

The stenosis of the hepatic veins has affected the portal circulation in much the same way as ordinary cirrhosis, interfering with the free flow of blood through the liver, and keeping the abdominal viscera in a condition of chronic congestion, the effect of which is very evident in the induration of the spleen and pancreas. The state of the liver is of interest as showing, in an exaggerated degree, the effects of congestion in the hepatic

[1] *Archives de Physiologie*, 1874, p. 897.

veins, presenting also certain peculiarities. The development of fibrous tissue is very much greater than is usually met with in the most chronic cases of heart disease or emphysema, amounting to a tolerably advanced cirrhosis. The new growth is much more intralobular than in the common form of this disease. Contrary to what might have been expected, the organ was not in an advanced state of red atrophy. The central veins of the lobules did not appear so distended as the secondary and tertiary branches of the hepatic veins.

In obliteration of the inferior cava the collateral circulation is usually carried on by the vena azygos, by means of its extensive communications with the lumbar and renal veins, being sometimes assisted by the superficial and deep veins of the abdomen and the anastomoses of the hæmorrhoidal plexus with the hypogastric and inferior mesenteric veins. In the present instance, also, this vein has been the main channel for the conveyance of the venous blood of the lower part of the body to the heart, and has, in addition, provided accommodation for a considerable proportion of the blood of the portal system. This is one of the most interesting features of the case. It certainly might have been expected, with so serious an obstacle to the flow of the portal blood as was offered by the stenozed orifices of the hepatic veins, that the superficial veins of the abdomen and thorax would have attained a maximum degree of distension. In Baillie's case, no mention is made of the state of the portal circulation; in that of Reynaud's the right branch of the hepatic vein was plugged. Veins of abdominal walls very large. In the clinical report the superficial cutaneous veins are stated to have been enlarged, but I learn from Dr Howard that at the time of his visit the enlargement was by no means remarkable, and this agrees with the condition found *post-mortem*. Nor were the deep abdominal and thoracic veins very much increased in size; and we must, therefore, suppose that the circulation has been carried on chiefly by the azygos. Part of the blood from the lower extremities and pelvis, entering the inferior cava and the large vein lying parallel to it, would find its way through the lumbars, the remainder, with that from the kidneys, would pass to the azygos through the communicating branches with the renals, and chiefly through the large vessel arising from the upper and

back part of the left renal, which, although its course was not traced, from its position and direction, must be regarded as a feeder of the azygos. The vertebral and dorsal cutaneous veins may have participated in carrying on the circulation.

It is not easy to determine the nature of the large vessel which passes from the iliacs on the left side along the aorta to the renal. The situation corresponds to the left spermatic, which has in several cases been found excessively dilated, and no other vein corresponding with the spermatic was found on this side. But why the free communication with the iliacs? The spermatic may have originally sent small branches to the iliac, which have subsequently dilated to such an extent as to appear as the direct continuation of the vessel. It was suggested, as some lumbar branches open into it, that it might be the azygos minor, which Henle[1] figures as connected with the common iliac; but, if so, why should it empty into the left renal? The situation and connections correspond exactly with a small vein, mentioned by Hallett[2] in his interesting paper, "which passes and establishes a communication between the common iliac vein and renal vein," and which, though not always present, may be considered normal. In the case of obliterated vena cava which he reports, it was enlarged and joined the ovarian vein.

From the absence of symptoms of obstruction in the portal system up to a short time before the fatal illness, we must conclude that a collateral circulation of sufficient activity had been established to compensate for the greatly narrowed streams from the hepatic veins. So far as was ascertained, this had taken place through the diaphragmatic and œsophageal plexuses, both of which were greatly distended. The veins of the falciform and round ligaments were moderately enlarged. It is not probable that any assistance was afforded to the portal system by the hæmorrhoidal veins through their connections with the inferior mesenteric.

The clinical history of this case, though in many respects incomplete, is very remarkable. In the first place, it must be admitted that the obliteration had lasted for some time, and did not occur during the last illness. The cord-like condition of the

[1] *Anatomie des Menschen*, Gefässlehre, p. 336. [2] *Loc. cit.*

obliterated part, the degeneration of the vein in the neighbourhood, the enlargement of the collateral branches, and the fact that for five or six years his legs were slightly swollen, point to an obstruction of long duration. Cases of occlusion are reported[1] in which life has been prolonged and tolerable health enjoyed for many years, an active collateral circulation obviating the effects of the obstruction; and among such this case may be reckoned. A difficulty here arises with respect to the hepatic veins. Are we to suppose that the narrowing to which their orifices have been subjected is of the same date as the closure of the inferior cava? or have the contracting fibrous cord and subsequent changes induced the degree of stenosis met with at the autopsy? To suppose that the extreme narrowing of these veins is of quite recent date would harmonise well with the clinical history and explain the rapid ascites, but the cirrhotic state of the liver, and the evidence of chronic congestion in the portal system, as well as the absence of recent changes about the hepatic veins, suggest an opposite conclusion.

It is not easy to give a rational explanation of the sudden development of the ascites. From the 12th to the 23d of December the patient suffered from symptoms of gastric and intestinal catarrh, and it was only on the latter date that swelling of the abdomen was detected. From this time until his death on 15th of January, the ascites became the prominent symptom, twice necessitating tapping the abdomen, each time with the removal of a large quantity of fluid. There was nothing in the condition of the portal and hepatic vessels to indicate any recent change which would explain the rapid accumulation of fluid, so that we must seek for the cause either in the blood or the state of the vascular walls. It may be that the attack of diarrhœa, which lasted from the 12th to the 20th, induced a depraved condition of the blood, or acted upon the portal vessels in such a way as to bring about that increased permeability of the walls, which, according to Cohnheim,[2] is the prime factor in dropsy.

However that may be, a parallel example is presented by certain cases of cirrhosis of the liver, in which a dropsical con-

[1] Robin, *Loc. cit.*

[2] Virchow's *Archiv.* Bd. 69. *Allgemeine Pathologie*, p. 375.

dition may develop with remarkable rapidity, and even without the common premonitory symptoms of gastric and intestinal catarrh. Such a case has recently been under the care of my colleague, Dr Ross, in the General hospital: the patient, a hard drinker, continued at work, and perfectly well (according to his own account, and after most careful questioning), up to December 23d. From this date dropsy of the legs and belly came on rapidly. On January 24, hæmatemesis set in, from which he died on the 27th. The liver presented an extreme degree of cirrhotic contraction.

The absence of albumen in the urine is a point worthy of note, and may, perhaps, be taken as evidence that the renal circulation was not additionally embarrassed during the illness. Reynaud,[1] to whose elaborate article I am much indebted, is the only author who dwells upon this symptom, stating that it might be useful as a diagnostic sign of the situation of an occlusion, whether above or below the renals.

And lastly, an interesting clinical feature of the case is the murmur described by Dr Howard. There was nothing found in the condition of the heart to account for it. Of possible sources the following suggest themselves:—(1) The vena azygos, though I am not aware of a murmur ever having been described in connection with this vessel; (2) The thoracic portion of the inferior vena cava, which formed a sort of appendage from the auricle, and into which the blood might be forcibly driven during the auricular systole, being unopposed by any powerful upstream in the cava.

Explanation of Plate XVII.

(View from behind.)

A, Obliterated inf. cava; B, orifices of hepatic veins; C, left renal; *d*, large branch which opens into it at the upper and back part; *e*, supplementary vein lying parallel to inferior vena cava; *f*, right spermatic (represented by the artist as too far posteriorly); *g*, orifices of lumbar branches of inf. cava, and supplementary vein.

[1] *Nouveau Dictionnaire de Médecine et de Chirurgie*, art. "Caves."

ON THE MALE GENERATIVE ORGANS OF THE KOALA. (*PHASCOLARCTOS CINEREUS*).

By Alfred H. Young, M.B., *Assistant Lecturer on Anatomy, Owens College, Manchester*. (Plate XVIII.)

Taking into consideration the position of typical pre-eminence amongst the Marsupialia which has been claimed for the Koala,[1] because of its manifold structural modifications, it is somewhat surprising to find that there are many points of anatomical interest of which, so far as I am aware, no detailed description exists.

Professor W. Boyd Dawkins recently placed at my disposal the well-preserved body of an adult male Koala, and so, by his kindness, afforded me the opportunity of investigating the sy.tomy of the species; whilst still more recently a second pecimen (also a well-developed male) having come into my possession, I have been enabled thereby to corroborate and verify former observations.

As a contribution to the anatomy of *Phascolarctos*, the object of the present paper is to point out the structural peculiarities of the genito-urinary system in the male: this I do with less hesitation, seeing that hitherto no complete account of them has been published.

Note.—In the following description all measurements are taken from the larger of the two specimens examined—this, from the tip of the nose to the end of the rudimentary tail, being 2 feet 2½ inches in length.

External Parts.

Immediately below the rudimentary tail is the anal aperture, beneath which the penis is situated. Bounding the base of this organ laterally are the prominent and expanded crúra of the penis, covered by the erectores muscles; whilst intervening between the crura and the body of the penis there are four

[1] *Cyclopædia of Anatomy*, vol. iii. p. 329, art. "Marsupialia."

prominent glandular-looking bodies, enclosed in muscular capsules. Of these, two are placed, the one above the other, upon each side of the penis. They may be considered, therefore, as being arranged in two pairs, the inferior of which are Cowperian glands, whilst the superior, indistinguishable in appearance from the inferior, are the bulbs of the corpus spongiosum. Other Cowperian glands are situated more deeply, and cannot be seen superficially in the normal position of parts.

The whole of these structures occupy what may be regarded as a common cloacal aperture, and are enclosed by a general muscular sphincter arrangement.

In the flaccid state of the penis this organ is retracted to such an extent that the glans is on a level with the basal glandular bodies above noted, amongst which it occupies a central position; in this condition it is almost entirely concealed by a hooded prepuce.

The *glans penis* measures three-fourths of an inch in length. Bifid at its extremity, it ends in two terminal lobes, the intervening cleft of which extends one-third the length of the glans; the lobes, internally, are simply grooved by the urethral canal, and present no special perforation, or basal apertures, such as exist in *Perameles lagotis*[1] or *Didelphys V.*[2]

Somewhat cylindrical in shape, the glans is slightly constricted near its base; there is, however, no distinct corona. Numerous strong retroverted spines are scattered over the external surface of the glans, with the exception of its free end.

The prepuce consists of a strong fold continuous above with the mucous membrane of the rectum. Superiorly it forms a hood, which conceals the greater part of the glans when the penis is retracted. Its inner surface, marked by circular rugæ, is seen when retracted to be continuous with the base of the glans, to which it is attached inferiorly by a distinct frænum.

Scrotum.—The scrotum is pendulous. It is situated in front of the penis, in that region of the abdominal wall which in the female is occupied by the marsupial pouch. The surface of the scrotum is covered with light downy hair of a yellowish colour.

[1] Owen, *Anat. of Vertebrates*, vol. iii. p. 647.

[2] Cowper, "A Male Opossum Dissected," *Phil. Trans.* 1704, (Jones' abridgment) vol. v. p. 174.

Internal Organs.

Kidneys and Ureters.—The kidneys, slightly reniform in shape, occupy a normal position in the abdominal cavity, that on the right side, however, being placed a distance equal to its own length, anterior to that on the left. Of equal size, the kidneys measure 2 inches in length and 1 in breadth at their broadest part. The external surface, except at the hilum, is perfectly smooth and uniform, there being no tendency to a lobar subdivision. Each renal organ is enclosed in a strong capsule. On section, the tubuli uriniferi are seen to terminate on a single ridge-like papilla, which does not project beyond the pelvis, as, according to Owen,[1] is the case in the Opossum. The ureters measure respectively 5¾ and 7½ inches. They enter the bladder just behind its neck, apparently, from an external inspection of the parts, close to the vasa deferentia, these latter, however, traverse wall of the urethra for some distance, and terminate in the ostatic portion of this canal.

Bladder and Urethra.—The bladder possesses a strong and thick muscular wall, the fibres of which are arranged in distinct broad bands; these surround the bladder in a circular manner, and are separated from each other by well-marked intervals. Generally, the direction of the muscular bands is transverse to the long axis of the viscus, but upon its lower surface, near the fundus, they assume a somewhat whorled character. The transversely banded arrangement is very evident on the dorsal and ventral surfaces of the bladder, whilst laterally it is concealed by a series of longitudinal fibres, which pass from the fundus to the neck; a smaller superficial longitudinal band of muscular fibres also runs between the same points along the middle line of the ventral or lower surface. When the walls of the bladder are contracted, the viscus assumes a somewhat triangular shape, the angles corresponding to the longitudinal fibres just described. In this condition the bladder measures 2 inches in length and 1½ in its greatest breadth. Its mucous lining, thick and soft, is thrown into longitudinal plications, which are somewhat irregularly disposed. The orifices of the ureters are placed upon slight mucous elevations, situated ¼ of an inch behind the urethral aperture.

[1] *Loc. cit.* p. 606.

The *urethra* extends from the neck of the bladder to the glans penis. According to its situation and character it may be conveniently divided into two portions,—an intra-pelvic and an extra-pelvic. The intra-pelvic portion extends from the neck of the bladder to the entrance of the Cowperian ducts. It measures $1\frac{7}{8}$ of an inch in length, and is almost equally divided into posterior or prostatic, and anterior or membranous parts. The prostatic portion is enclosed in the substance of a well-developed prostate gland; this, though of large size, is small as compared with that of many marsupials. It measures $\frac{7}{8}$ths of an inch in length and $\frac{5}{8}$ths in its greatest diameter. Pyriform in shape, its broad end is next the neck of the bladder; in this portion, a well-marked antero-posterior depression on its rectal aspect breaks the otherwise uniform surface of the gland, and shows its tendency to a bilobar condition. The membranous part of the urethra measures 1 inch in length. Its walls are uniform in calibre, and surrounded by muscular fibres. On slitting open the intra-pelvic urethra, a well-marked veru-montanal eminence is seen in the prostatic part, extending as an elongated ridge into the membranous region. On the floor of the urethra on each side of this eminence, the orifices of numerous prostatic ducts are visible.

The veru-montanal eminence is marked at its summit by a shallow depression, representing an ill-defined utriculus, or sinus pocularis. On the sides of this, and opening distinctly into it, are the minute orifices of the seminal ducts. Leuckart has previously described a similar arrangement, though of a much more marked character as existing in the hare and rabbit, and writes thus: "But the most extraordinary circumstance about the utriculus in these animals is this, that it receives the ejaculatory ducts. In all other instances, these open independently by its sides into the urogenital canal; but here, departing from this rule, they open into the undermost part of the Weberian organ."[1] That this rule is by no means so constant as supposed by Leuckart has already been shown—a similar condition existing in the Elk,[2] and in *Hyæna crocuta*,[3] and now, again, we find it in the Koala.

[1] Todd's *Cyclopædia*. art. "Vesicula Prostatica," vol. iv. p. 1419.

[2] Watson and Young, "Anatomy of the Elk," *Proc. Linn. Soc.* vol. xiv. p. 375

[3] Watson, *Proc. Zool. Soc.* April 1878, p. 419.

The extra-pelvic, or spongy portion of the urethra, measures 3 inches from the entrance of the Cowperian ducts to the terminal end of the glans penis. It is situated within the penis, being surrounded almost entirely by the corpus spongiosum of that organ.

Testicles, and Vasa deferentia.—The testicles, each about the size of a horse-bean, are lodged in the prepenial pendulous scrotum. Each is provided with an epididymis, which, as usual in marsupials, is very loosely attached to the corresponding testicle, and in which the respective parts are easily discernible. The vas deferens on either side measures 6 inches in length, taking the usual course through the abdominal wall, and reaching the posterior border of the prostate gland each vas here lies in contact with, but external to, the ureter of the corresponding side. Continuing perfectly distinct and separate, the vas deferens of each side traverses the substance of the prostate to end upon the sides of the so-called vesicula prostatica, as previously described. The lower end of the vas deferens is simple, and, as is the case with all marsupials,[1] presents no trace of lateral diverticula; in other words, there are no vesiculæ seminales, though Martin asserts their presence in a Koala examined by him.[2] Referring to the absence of vesiculæ seminales in the Opossum, Cowper[3] suggests that compensation is provided by the comparative large size of the epididymis.

Cowper's glands.—Situated at the root of the penis are six glandular bodies so named. They are arranged in three pairs, the disposition of which closely resembles that of the corresponding structures in *Hypsiprymnus*, as figured by Professor Owen.[4] Enclosed within the sphincter cloacæ, each Cowperian gland is also provided with a well-developed muscular capsule. Of the respective glands, one pair, considerably smaller than the others, is placed close to the junction of the crura penis, a small backward projection of the corpora cavernosa intervening to some extent between the glands of opposite sides. Both of these are

[1] Gegenbaur, *Elements of Comparative Anatomy* (Bell's translation), p. 618; also *Cyclopædia of Anatomy*, vol. iv. art. "Vesiculæ Seminales."

[2] Martin, "Notes on the Anatomy of Koala," *Proc. Zool. Soc.* Part iv. 1836, p. 112.

[3] *Loc. cit.* p. 170.

[4] *Anat. of Vertebrates*, vol. iii. p. 646.

retained in the position indicated by reason of the attachment to the fibrous walls of the corpora cavernosa of the muscular fibres which form the gland capsules. Almost three times the size of the glands just referred to, each gland of the remaining two pairs has a diameter of nearly half an inch. The investing muscular fibres have no attachment to the surrounding structures, so that these glands are quite free; their ducts measure 1 inch in length, those of the same side unite together and form a common duct, which, after receiving superiorly the short duct of the small attached gland of the corresponding side, opens into the urethra, at the junction of its membranous and spongy portions.

Martin does not describe in detail these glands in the Koala examined by him, whilst from his description of what he names the vesiculæ seminales in that specimen, it seems probable that he has mistaken either one pair of Cowperian glands, or else the bulbs of the corpus spongiosum for these structures. His words are: "The vesiculæ seminales are small; they entered $\frac{7}{8}$ths of an inch below the bladder, with Cowper's glands,"[1]—an error which is difficult to understand, considering the distance which intervenes between the vasa deferentia and the so-called vesiculæ seminales.

Close to the Cowperian glands, and so nearly simulating them in appearance that they may easily be mistaken for an additional pair, are two rounded and pedunculated bodies, the external surface of which is covered over by a muscular layer. These are, however, not glands, but simply the posterior bulbs of the corpus spongiosum, with which they will be described.

Penis.—The penis measures 3 inches in length. It consists of cavernous and spongy portions as usual.

The corpora cavernosa commence by large expanded crura, which have no attachment to the bony pelvis, but, remaining quite separate, form rounded bodies of considerable size. The erectores penis, investing the crura, are also distinct from the pelvis; the sphincter cloacæ, indeed, intervenes, and there is no such attachment as Owen describes[2] in Potoroos and Kangaroos; in this respect the Koala agrees with the Opossum.

[1] Martin, *loc. cit.* p. 112.

[2] *Anat. of Vertebrates*, vol. iii. p. 313.

The crura soon come into contact, and with the corpus spongiosum form the body of the penis. At their junction, and occupying a superior position, is a well-marked backward projection, which separates the two smaller Cowperian glands, and affords attachment to the muscular fibres investing them.

The corpus spongiosum, as in all described marsupials, presents posteriorly a double bulb, the two halves not having united during development, to form the single bulb as in most male mammals. Correspondingly, the investing muscle (bulbo-cavernosus) is also divided to form a muscular capsule for each bulb. This double character of the bulb is considered by Cowper[1] to be necessary "to maintain the turgescence of the double or forked glans," so characteristic of most marsupials. It has been already stated that the bulbs, both in shape and size, closely correspond to the Cowperian glands. This resemblance is rendered more striking and misleading, by reason of the length and narrowness of the erectile tissue extending from the bulbs to the point where the corpus spongiosum comes into contact with the urethra, a distance of about half an inch. Here, indeed, it is reduced to a narrow pedicle, which, covered by dense fibrous tissue, looks extremely like a duct, and, with the expanded bulb, closely simulates a Cowperian gland and its duct. In the Opossum, the pedicle being short and thick, the bulb no longer has the appearance of being pedunculated, and can hardly be mistaken for a Cowperian gland. The corpus spongiosum, reaching the urethra, almost entirely encloses it, ending anteriorly in the glans.

Muscles of Penis.

Having an important influence in the erection of the penis, and, consequently, to be regarded as one of its muscular agents, the *Sphincter cloacæ* is included under this heading. In the Opossum, Cowper[2] considers it to be the chief agent in continuing the erection of the penis, and points out that "the muscles of the cavernous bodies of the penis of this creature having no connection with the os pubis, cannot apply the dorsum penis to the last-named bone, whereby to retard the effluent blood

[1] *Loc. cit.* p. 174. [2] *Loc. cit.* p. 137.

and cause an erection, as we have observed in other creatures."

The *sphincter cloacæ*, conveniently so named, encloses even in the male both the anus and the urogenital orifice. In the Koala it consists of an external stratum of muscular fibres, which, commencing broad beneath the coccyx, but having no direct attachment to it, passes on each side of the penis, anus, and glands, and surrounds all. Converging, the fibres form a rounded bundle over the dorsum of the penis. Another set of fibres, united with these in the latter situation only, surround the penis and anus, forming a deeper stratum. The Cowperian glands, and the bulbs of the corpus spongiosum, are situated between the two strata, these latter being connected by intermediate muscular fibres which pass between the glands. None of the fibres have any attachment to the pelvis.

Ischio-cavernosi form strong muscular coverings of the crura. These fibres, as before stated, have no bony attachment.

Bulbo-cavernosi consist of muscular fibres, which, in a similar way, enclose the bulbs of the corpus spongiosum.

Retractores penis. These are placed on the under surface of the penis. Two in number, each muscle, which is somewhat riband-like in character, springs from the pelvic surface of the sacrum, crosses the cavity of the pelvis, and, running on the lower aspect of the corpus cavernosum, terminates at the base of the glans.

Levator penis. This muscle, apparently first described by Cowper in the Opossum,[1] was considered by him as peculiar to that animal. According to Owen,[2] however, it exists in all marsupials possessing a bifid or forked glans, whilst it is absent in the Kangaroo. In the Koala it arises by a fascial origin from the crus penis; fleshy fibres soon appear, and, converging, unite with fibres similarly originating from the opposite crus, to form a muscular arch, the convexity of which is directed forward. In one of my specimens an additional mesial muscular bundle, springing from the backward projection situated at the junction of the crura, joined the arch. Anteriorly, the muscular fibres end on two delicate tendons, which, joining together more or less, terminate on the dorsum of the penis near the glans.

[1] *Loc. cit.* p. 173. [2] *Anat. of Vebetrates*, vol. iii. p. 648.

Cremaster.—This muscle is conveniently described here. Very strong, it has an attachment to the crest of the ilium by fascia, and does not spring from the internal oblique, as found by Martin.[1]

Concluding Remarks.

In respect of the principal features of its generative system, the male Koala is essentially marsupial. In the foregoing description, however, certain points may be found which, when compared with what obtains not only in other marsupials, but also in the monodelphous mammalia, are of some considerable interest, both morphologically and developmentally. To such it seems advisable that some further reference should be made.

So far as regards the internal organs of generation, Koala differs but slightly from other marsupials. Such differences as do exist, are to be found in the respective lengths of the prostatic and membranous portions of the urethra; as previously noted, these in the Koala are almost equal, the prostatic portion, and, consequently, the prostate gland, measuring $\frac{7}{8}$ths of an inch, whilst the membranous portion is slightly longer, and measures 1 inch. With the exception of the Wombat,[2] in other marsupials the prostate gland is apparently very much longer in comparison, and considerably exceeds in length the membranous part of the urethra—*e.g.*, in an Opossum in which "the length of the urethra between the bladder and the penis exceeded 4 inches," 3½ inches were enclosed by the prostate gland. Cowper,[3] giving these measurements, considers it a provision to allow of extrusion of the penis during erection, the prostatico-membranous part of the urethra in this animal being much contorted and folded during retraction of the organ. In the Koala, however, the contortion during retraction of the penis is not intra-, but extra- pelvic, the whole of the penis, and also the Cowperian glands, remaining outside the pelvic cavity, and, along with the pedunculate scrotum, constituting the external organs of generation. In the Opossum, these latter, except during protrusion of the penis, being practically limited to a non-pendulous prepenial scrotum.

[1] *Loc. cit.* p. 110.
[2] *Cyclop. of Anatomy*, vol. iv. p. 161, art. "Prostate Gland."
[3] *Loc. cit.* 172, 173.

Professor Owen,[1] referring to the large size of the prostate gland in marsupials, suggests, as in some degree explanatory of the circumstance, that, "as the part of the urethral canal immediately succeeding the termination of the sperm ducts is the homotype of the vagina, some modification of this part might be anticipated in the male, corresponding with the extraordinary form and development which characterise the vagina in the female; accordingly we find that the prostatic tract of the urethra is proportionately longer and wider in the marsupial than in any other mammal." Granting even that Professor Owen is right regarding the homotypical relations of that part of the urethra specified and the vagina, still it is not quite clear why this should in any way be connected with the large size of the prostate gland. That it is not so universally, even amongst marsupials, is evidenced by the case of the Wombat, in the male of which the existence of a prostate is doubtful (Adams[2]). But it does not appear at all likely that the hypothesis with reference to the homotype in the male of the vagina, upon which the conclusion regarding the large size of the prostate is based, is tenable; on the contrary, it seems quite certain that this is to be found, not in any part of the urethral canal, but in such vestiges of the Müllerian ducts as may remain in the male, whilst "the portion of the urethra immediately succeeding the entrance of the sperm ducts" is to be regarded as homologous with the sinus urogenitalis or its vestibular representative.

Considerable light has been thrown on the homologies of the various parts of the sexual apparatus in the two sexes by the observations of Professor Watson,[3] with reference to the remarkable arrangements of the genito-urinary organs in *Hyæna crocuta*. In this animal the homology of that part of the urethra immediately succeeding the entrance of the sperm ducts with the commencement of the urino-genital canal in the female is as Dr Watson says, "conclusively proved." Equally certain it is that this part of the urino-genital canal in the female *Hyæna crocuta* does not correspond to what is ordinarily known as a vagina in most female mammals; but to what in them is metamorphosed into

[1] *Loc. cit.* vol. iii. p. 645.
[2] *Cyclop. of Anatomy*, vol. iv. p. 161, art. "Prostate Gland."
[3] *Proc. Zool. Soc. Lond.*, May 1877, p. 370, and April 1878, p. 416.

a vestibule. The condition of these parts in the Spotted Hyæna, whilst it completely refutes the view of Owen, confirms in a very definite manner that adopted by most modern embryologists.

Amongst marsupials, the males of which as a class possess large prostates, the Koala may be regarded as characterised by a prostate gland, which, though extensive, is still comparatively small, whilst moreover, it is peculiar as showing indications of a division into two lobes. The corresponding portion of the urethra presents internally a veru-montanal eminence, remarkable by reason of the so-called utriculus, which exists as a shallow depression on its summit, and receives the openings of the seminal ducts.

Whether this utriculus or vesicula prostatica is to be regarded as the homologue of the vagina alone, of the uterus alone, or of both, in the female marsupial, is difficult to say.

The greater number of embryologists, including Leuckart, Wahlgren, Kölliker, Thomson, and even Meckel,[1] seem now agreed that the Weberian organ is the morphological equivalent of both uterus and vagina in those mammals, the females of which possess both structures; whilst when the females lack the vagina, as in the Indian Elephant and Spotted Hyæna,[2] then it can no longer be looked upon in this light, but may be regarded as a true "uterus masculinus" representing the uterus solely.[3] Inasmuch as in these latter animals the whole of the Müllerian ducts in the progress of their developmental changes become metamorphosed into the uterus,[4] whilst in other female mammals the genital canal thus derived becomes so differentiated, that the upper part constitutes an uterus and the lower a vagina. It is clear that, even in the somewhat exceptional cases of the Indian Elephant and the Spotted Hyæna, the vaginal canal is morphologically present in the lower end of the uterus, though functionally it is represented by the sinus urogenitalis.

[1] *Cyclop of Anatomy*, vol. iv. art. "Vesicula Prostatica."

[2] Watson, *loc. cit.* p. 424. [3] Leuckart, *Cyclop. of Anatomy*, vol. iv. p. 1427.

[4] Miall and Greenwood dispute the assertion as to the absence of a vagina in the Indian elephant, stating that "the united Müllerian ducts appear to us to be plainly divisible (above the urogenital canal) into two parts, which are separated by a constriction and differ in internal structure. The upper part seems to us to represent the uterus, and the lower the vagina, while the internal thickening may well represent an os uteri" (*Journal of Anatomy and Physiology*, vol. xiii. pl. i. p. 31).

In all cases, then, the Weberian organ represents the genital canal, formed by the conduits of Müller, be it differentiated into vagina and uterus or not. In the Koala the case is somewhat different, and the true homological significance of its Weberian organ is not easy to determine. Seeing, however, that in the female marsupial the Müllerian ducts either remain entirely separate, or, if not, that their coalescence is confined to their vaginal ends, it appears more rational to regard the utriculus in the Koala as the homologue of the vagina only.[1]

Remembering, however, the close relationship of the Müllerian and the Wolffian ducts in the genital cord, it does not seem impossible that the minute recess or utriculus so-called may in no wise be formed from the Müllerian ducts, but may simply represent a coalescence of the lower ends of the Wolffian ducts.

In no other marsupial has a Weberian organ been described, whilst in many—*e.g.*, *Halmaturus giganteus*, *Phascolomys wombat*, *Sarcophilus ursinus*, *Didelphys virginiana*—its absence is definitely affirmed.[2]

In the possession of three pairs of Cowperian glands, the Koala agrees, apparently, with the majority of marsupials;[3] in some, however, this number may be increased to four,[4] whilst in the Opossum it is reduced to two.[5]

In the Koala the bulbs of the corpus spongiosum, as in all marsupials, remain separate; this retention of a condition peculiar to the females of most mammals contrasting somewhat forcibly with the almost entire absence of feminine indications in the internal generative organs of male marsupials.

The Koala presents only in a minor degree the tendency to the forked character of the glans penis which exists in many species. According to Owen,[6] it closely agrees with the Wombat in this respect, and with it occupies an intermediate position between the uniparous marsupials, in which the glans is undivided and single, and the multiparous species, in which it is distinctly bifid.

[1] Gegenbaur (*loc. cit.* p. 619) apparently holds this view of the homological significance of the Weberian organ to be applicable to most mammals.

[2] *Cyclop. of Anatomy*, vol. iv. p. 1428, art. "Vesicula Prostatica."

[3] Owen, *loc. cit.* p. 646.

[4] Gegenbaur, *loc. cit.* p. 623.

[5] Cowper, *loc. cit.* p. 172.

[6] *Loc. cit.* p. 647.

Lastly, I may refer to the absence in *Phascolarctos* of the anal glands, so well marked in *Didelphys virginiana.* In the latter animal a single large gland is situated on each side of the rectum, opening into it about a quarter of an inch from the anal aperture.

EXPLANATION OF PLATE XVIII.

Fig. 1. Male generative organs of the Koala, rectal surface (natural size). *B.* Bladder. *UU.* Ureters. *TT.* Testicles (covering removed from left to show the epididymis). *V.D.* Vasa deferentia. *P.G.* Prostate gland. *G.P.* Glans penis; prepuce retracted. *R.P.* Retractores penis. *Pe.* Penis. *c.p.*, *c.p.* Crura penis, with erectores partially reflected. *b.s.*, *b.s.'* The two separate bulbs of the corpus spongiosum. $c.g.^1$ $c.g.^2$ $c.g.^3$ Cowper's glands (three pairs).

Fig. 2. Pubic aspect of the penis. *L.P.* Levator penis; other letters as in fig. 1.

Fig. 3. Intra-pelvic portion of the urethra laid open to show the veru-montanum and the utricular depression. The two bristles are placed in the openings of the ureters.

ON SOME BONES OF A FOSSIL SEAL FROM THE POST-TERTIARY CLAY AT DUNBAR. By D'ARCY WENTWORTH THOMPSON, *Student of Medicine, University of Edinburgh.*

IN the month of November 1878, my attention was directed, through a paragraph in the *Scotsman* newspaper,[1] to the occurrence of certain mammalian bones in the brick-clay at Dunbar. On making further inquiry into the matter, the bones were very kindly sent to me by Mr Brodie Sheriff, the proprietor of the works, and they turned out to be the long bones of the left fore-limb of a small though full-grown seal. The epiphyses were completely ossified, and the muscular ridges and impressions strongly marked.

Remains of seals have, as is well known, been met with already on several occasions in the brick-clays of various parts of Scotland, and the specimens hitherto found seemed all to be referable to a single species, which has been identified by Professor Turner,[2] as indistinguishable from the floe rat or *Phoca hispida*, of Cuvier.[3] But the present examples, though the evidence they furnish is not definite enough to permit of any very precise conclusions with regard to the species to which they belong, yet differ so considerably from those previously obtained, as to be of somewhat more than ordinary interest. In the first place, the humerus is seen to be devoid of the ento-condylar perforation, which is so well known a feature in this genus, and, indeed, as Prof. Turner tells me, is probably a characteristic feature in the whole of the Arctic seals. Of course, just as in the human subject we meet now and then with this foramen in the shape of the hook-like process, with a fibrous prolongation to the condyle, situated a short distance above the internal condyle, so it is perfectly conceivable that an individual seal might, varying in the opposite direction, have been devoid of a structure which was nevertheless a common attribute of his species; but the fact is, for all that, remarkable.

Leaving aside this point for the present, the bones from Dunbar

[1] The *Scotsman*, Nov. 20th, 1878.

[2] *Journ. of Anatomy and Physiology*, vol. iv. pp. 256–270.

[3] *Pagomys fœtidus*, Gray, Brit. Mus. Cat. p. 23.

approach most nearly in size and general appearance to those of the largest seal from the clay preserved in the Anatomical Museum of the University of Edinburgh, viz., a fine adult specimen from Montrose, which, with bones of seals from other localities, is ascribed by Professor Turner to *Phoca hispida.* But on comparing the Dunbar bones more carefully with the corresponding limb of the Montrose seal, the following points of divergence become apparent.

The bones from Dunbar are slightly the larger, but are not so broad as the others in proportion to their length. The sharp external border of the humerus is in the Montrose specimen shorter and more curved than in that from Dunbar; the external supra-condyloid or supinator ridge is more developed, forming a thin expanded vertical ridge, which slopes considerably backwards, and adds greatly to the breadth of the lower part of the bone, especially when viewed from the posterior aspect: also the impression of the supinator muscles extends higher up along the margin of the ridge than in the Dunbar example. In the latter, the ridge is thicker and not so much expanded, and bears another roughened muscular line in front, a short distance internal to, and parallel with its outer border; this, by the way, is seen also in *Halichœrus gryphus.* In connection with the upper portion of the bone, the ridge which bounds the bicipital groove on the outer side—that is to say, the internal border of the downward prolongation of the great tuberosity—is in the Dunbar specimen less elevated; and the upward continuation of this ridge arches over to approximate less closely to the small tuberosity. Again, the lesser tuberosity is longer, not so thick, nor so much inclined forwards, and the bicipital groove lying between is slightly narrower and more restricted. The impression of the latissimus dorsi is round, and very well defined; not so in the bone from Montrose, which, however, exhibits a stronger deltoid impression. The broad, expanded, raised surface, which is prolonged downwards from the great tuberosity, is more rough and uneven in the Montrose specimen, and its lateral borders, which in descending converge a good deal in the other, are here parallel. The external lateral border is sharp and overhanging in both, but to a much greater extent, and forming a much deeper groove or hollow beneath it, in the Montrose specimen.

The inferior articular surfaces present no marked differences. save that the trochlea extends a little further upwards posteriorly in the Dunbar example, and the olecranon fossa is a shade deeper and better marked.

Lastly, as has been already noticed, the round foramen, or rather short canal, which in the Montrose specimen and in others extends downwards and forwards above the internal condyle for the transmission of the median nerve, being formed by a flat bridge of bone stretching from the internal condyle to the shaft of the humerus, is entirely absent in the bone from Dunbar. Hence the muscular impressions of the inner condyle, which, as a rule, extend upwards somewhat, on to the bar of bone, are here less developed, and more restricted; and hence also, in the present instance, the breadth of the lower portion of the bone is still more curtailed (*see woodcut*).

The points of difference which may be noted in connection with the bones of the fore-arm are less numerous and less definite than those exhibited by the respective humeri. The ulna of the Dunbar seal is longer and more compressed, and the hatchet-shaped olecranon rises considerably higher above the great sigmoid cavity. On the other hand, the radius, though longer, is less compressed and expanded, and the neck is longer and more cylindrical. This greater flattening and expansion, especially of the lower part of the Montrose bone, leads to the outer border being much more curved; and also to the grooves for the flexor and extensor tendons being broader and shallower than in the other specimen, and the intervening ridges and eminences less strongly marked.

The following are the relative dimensions of the bones:—

		Dunbar.	Montrose.
Humerus	Length from the head of the bone to the capitellum, . . .	4·1 in.	3·8 in.
	Length from the top of the lesser tuberosity to the internal condyle,	4·3	3·8
	Length from the top of supinator ridge to lower part of head, .	1·95	1·4
	Breadth at level of middle part of supinator ridge, . .	1·35	1·6
Ulna	Extreme length, ...	5·2	5·0
	Length of crest of olecranon from before backwards, . .	1·8	1·7
Radius	Extreme length, . . .	4·15	3·95
	Breadth at lower end, anteriorly, .	1·4	1·5

...red is well known ... yielded the little ... llman,[1] and speci-

... humerus of Dunbar ... Seal.

... the absence of the ... bearing on the ... n sake, a point of ...

... 360.

ON A NEW VARIETY OF OCULAR SPECTRUM.

By JOHN AITKEN.

IF we look for a short time at any object, and afterwards turn the eye in another direction, we see a spectral image of the form of the object first looked at.

Again, if after we have looked at any coloured object we turn the eye in another direction, we see a spectral image of a colour complementary to that first looked at.

In addition to these spectral forms and colours, I find there is another and distinct kind of ocular spectrum, which we may call a motion spectrum. It is seen when we look first at a body in motion and afterwards direct the eye towards an object at rest. The object at rest, when seen under these conditions, seems to be in motion, and the direction of its apparent motion is the opposite of that of the moving body first looked at.

I first observed this motion spectrum when looking at the surface of a river where it was flowing rapidly, the eye being afterwards directed to a gravel bank. The first effect seemed to be an indistinctness of vision, but, on carefully repeating the experiment, I was much astonished to observe that, after looking steadily at the stream and then at the gravel bank, a narrow spectral stream of gravel seemed to flow steadily through the middle of the gravel bank, the direction of its motion being the opposite of that of the river. Sir D. Brewster made some experiments while looking out of rapid-moving trains on the effect of images moving rapidly across the retina, but he does not seem to have observed these motion spectra. Professor Silvanus P. Thompson has, however, observed a somewhat similar phenomenon.[1] He says:—"If, from a rapid railway train, objects from which the train is receding be watched, they seem to shrink as they are left behind, their images contracting and moving from the edges of the retina towards its centre. If, after watching this motion for some time, the gaze be transferred to an object at a constant distance from the eye it seems to be actually expanding and approaching."

[1] *Report of the British Association*, 1877.

...spectra are not easily ...ey require special ...distinctly observed. ... extremely simple, ... for showing them

... painted as shown in

Fig. 1.

... If after looking ...ye is directed to the ...ars to be rotating in ...ng disc. Or we may ... of paper having a ...king at the rotating ... in which the mark- ...onary, but all seem

... cm. to 44 cm. in diameter. ...es not seem to be of much ...y requires to be driven at ...y be driven quick enough ...t the aid of multiplying

...eye cannot distinguish the ...are blended together.

...rongly contrasted with the ...will do, but the effect is ...The best effect is produced ... thick enough to make the ... all over with Indian ink. ...t does well.

moving in a circular direction, like a slow-moving whirlpool, the direction of the motion being the opposite of that of the exciting disc.

In these cases the motion was circular, and the result was a circular spectral motion. We may, however, vary the experiment, when we shall find that the spectrum will always correspond to the exciting motion. Suppose we take an endless band of paper, with black bars painted across it, and pass it over two drums revolving on horizontal shafts, one placed over the other, so that the paper band shall move in a straight line either upwards or downwards. If, while this band is in motion, the eye be fixed upon it for a short time, and then the gaze be directed to the mottled paper, a spectrum of the moving band will be seen. A narrow strip of the mottlings will appear to flow through the mottled sheet of paper, reminding one strongly of the appearance of a lava stream, the breadth of the stream corresponding to the breadth of the moving paper band, and the direction of its apparent motion being the opposite of the moving band first looked at.

Or we may vary the experiment in this way:—Take a wheel, having spiral spokes coloured black, and rotate it in front of a disc similar to that first described, but in this case kept stationary, so that the white parts seem to travel from the centre to the circumference, or from the circumference to the centre of the disc, according to the direction in which the wheel is turned. If the mottled paper is looked at after looking at the apparatus in motion, all the mottlings in the spectrum seem to be in motion, either towards the centre or the circumference, according to the direction of the motion of the real impression.

These motion spectra are also seen if the eyes are closed after looking at the moving body, the spectrum of the moving paper band suggesting a phantom shower of rain in sunshine, the direction of the apparent motion being the opposite of that of the real impression.

It might be thought, since the spectrum of the moving band seen on the mottled paper seems to be in motion, and as some of the mottlings seem to flow past the others, that if we were to draw a straight line across the spectral stream, the line ought to appear bent, because it might be expected that the part of the

line in the stream would appear to move forwards. Such, however, is not the case. So far as my experiments go, I have never seen the least appearance of a bend produced in a straight line; indeed, the straight line does much to stop the apparent motion. Again, in the first experiment with the circular disc, if we make the drawing, at which we afterwards look, larger than the exciting disc,—as, for instance, by extending the spokes of the wheel to a greater size than the rotating disc,—then this extension will entirely destroy all appearance of rotation, and the wheel will appear at rest. Do not these last experiments suggest that the seat of the illusion is deeper than the retina? I shall not, however, attempt to answer this question, as the experiments do not point to any definite conclusion.

Experiments were also made to determine the effect of influencing the whole retina. This was done by looking so closely at the moving band that its image covered the whole retina, but no decided effect was noticed. Experiments were also made with the same object by means of a large box-shaped arrangement, the sides of which were made of tracing paper having vertical bands of black paper 4 cm. broad and fixed 4 cm. apart. The observer being seated in a chair, the box was let down over him and put in motion, which was continued some time; the box was then raised, but no appearance of motion in surrounding objects was observed. There were, however, some curious effects produced by the rotation of this apparatus. At certain times, while surrounded by the rotating box, the observer felt as if rotating in the opposite direction. The most certain result, however, was a most disagreeable sickening effect, which continued for some time after the experiment was made. The effect of this rotating apparatus might form an interesting study in connection with the important investigation at present conducted by Professor Alex. Crum Brown on the function of the semicircular canals of the ear.

SOME POINTS CONNECTED WITH THE PHYSIOLOGICAL ACTION OF PILOCARPINE. By JOHN SERVICE, M.D., *Assistant to the Professor of Clinical Medicine in the University of Glasgow, &c.*

PILOCARPINE ($C_{23}H_{34}N_4O_4$) is the only alkaloid of jaborandi (*Pilocarpus pennatifolius*).

Jaborandi was first introduced to the profession in the year 1873–1874 by Dr S. Coutinho of Pernambuco,[1] as a powerful diaphoretic and sialagogue; and its alkaloid was isolated by A. W. Gerard of London in the beginning of 1875.[2]

That jaborandi possesses sudorific and sialagogue properties in a high degree, there can be no doubt; but its alkaloid, pilocarpine, exhibits such advantages over the mother plant, that it now only is used. This, however, is not the place to enumerate these advantages.

Though in the present paper it is only intended to show graphically the effect of pilocarpine on the circulatory organs, it may be mentioned that this interesting drug *never* fails to produce profuse sweating and salivation, when given subcutaneously and in doses large enough, namely, from a sixth to half a grain of the nitrate. Given to an adult, I have never seen a third of a grain fail—the diaphoresis persisting for two or three hours.

Pilocarpine seems to act by paralysing the vasoo-motor nerves; for almost instantaneously on its injection under the skin, the face flushes, the whole skin becomes warmer, and the heart's contractions are increased in number. If the fingers be placed upon the pulse, besides noticing that the rate is increased, it will also be observed that it becomes larger, more easily compressible, and more dicrotic. But this will be best understood by reference to the following sphygmograms, which were taken from the radial artery of a man recovering from an acute attack of tubular nephritis. The pressure employed throughout was 5 oz.

[1] *Répertoire de Pharmacie*, vol. ii. p. 171.
[2] *Pharmaceutical Journal*, May 1, 1875.

...n of the drug, shows

... the nitrate of pilo-
... the left forearm.

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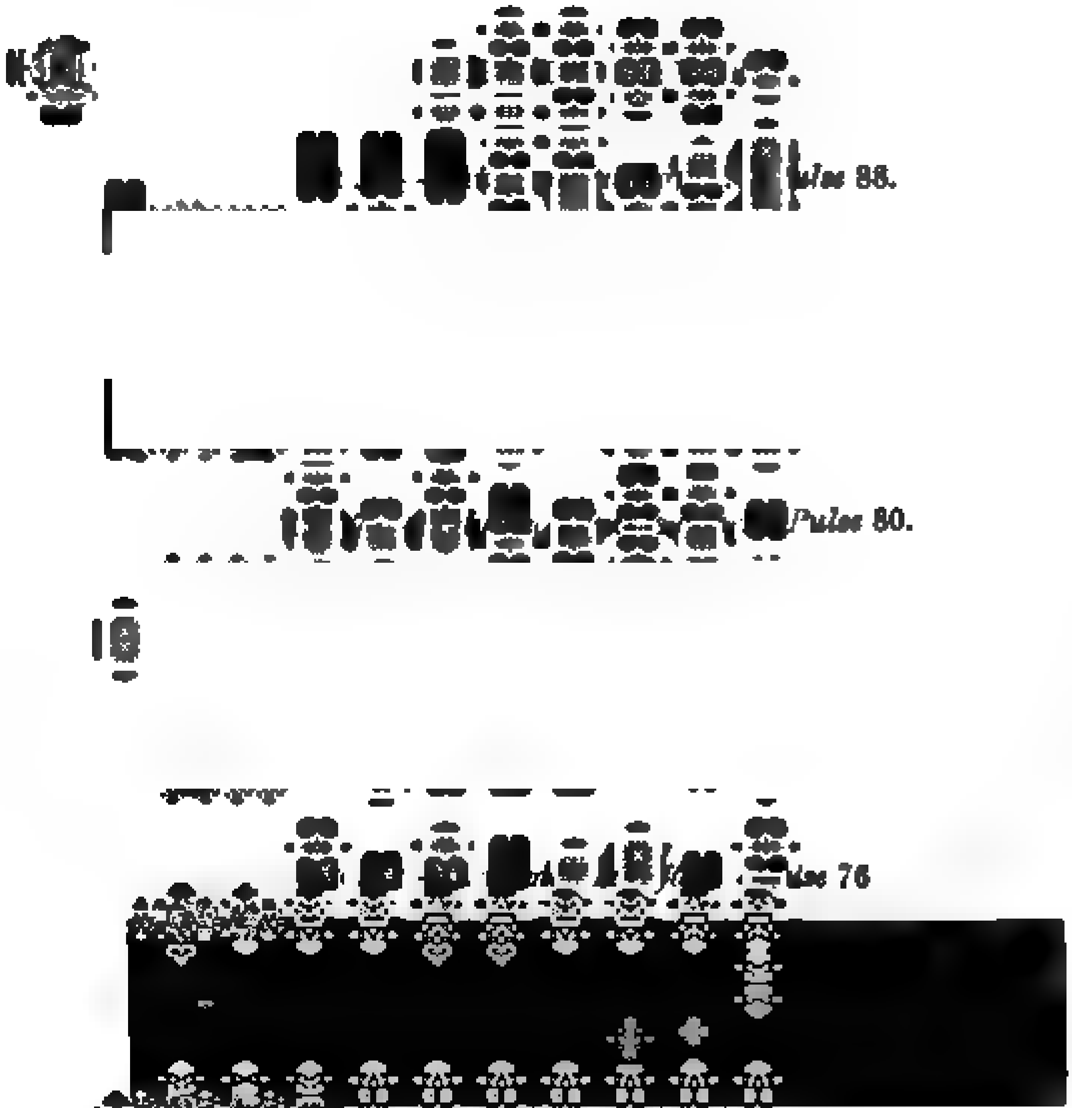

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OF PILOCARPINE.

atropia. *Pulse* 76.

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phygmograms. They

ON THE CIRCULATORY SYSTEM OF MAGELONA.*

By W. C. M'INTOSH, M.D., F.R.S.S.L. and E.

No feature is more striking in the anatomy of this Annelid than the fact that the blood is a densely corpusculated fluid, and, moreover, that the corpuscles are of a pinkish colour. The views of at least one predecessor in this field will therefore require modification, especially as they have been pronounced in no ambiguous terms. In the *Philosophical Transactions* for 1852, Dr Thomas Williams observes:[1] "Investigations on an extended scale, and conducted with the strongest desire for real truth, enable me in this place to state most confidently that in the descriptions cited, both from M. Milne-Edwards and Mr Wharton Jones, these distinguished observers have fallen into the most extraordinary errors. *In no single species among the Annelida does the blood proper contain any morphotic elements whatever!* In all instances, without exception, it is a perfectly amorphous fluid, presenting under the highest powers of the best microscope no visible corpuscles or molecules or cells of any description whatever. It is a limpid liquid, variously coloured, as formerly and correctly stated by M. Milne-Edwards, in different species." Long before this was written, however, Rud. Wagner had found corpuscles in the blood of a *Terebella*. M. de Quatrefages again observes,[2] that there are exceptions to the rule above mentioned, and adduces *Glycera*, *Phoronis*,[3] and *Syllidia armata* in support of his statements. As M. Claparède has pointed out, the corpuscles in the case of the first mentioned, like those of *Capitella*, belong to the perivisceral cavity, while the second must be relegated to the *Gephyrea*. *Syllidia armata* has a large dorsal and a ventral contractile trunk, communicating by branches, and the yellowish blood contains navicular

* See *Zeitsch. f. w. Zool.* Bd. xxxi. p. 401, pls. 29 to 38, for a complete account of the anatomy of this form.

[1] *Philos. Trans.* 1852, part ii. p. 632. See also *Report Brit. Assoc.* 1851, p. 175.

[2] *Annelés*, part i. p. 63, and ii. p. 15.

[3] Kölliker, *Kurzer Bericht, &c., an der Westkuste von Schottland*, 1864 (Separat-abdruck, p. 11).

globules $\frac{1}{1000}$ of a *millimetre* in length and $\frac{1}{1800}$ in thickness, their form differing quite from that of the perivisceral globules. The late M. Claparède found corpuscles in the blood proper of certain Staurocephalidæ, in several Cirratulidæ (e.g., *Cirratulus chrysoderma* and *Audouinia filigera*), and in certain Opheliidæ (e.g., *Ophelia radiata*, and others).[1] Various authors have mentioned the presence of corpuscles in the blood of the earthworm,[2] and the occurrence of such globules in the blood of the Nemerteans has also been pointed out.[3] Though in *Magelona* the corpuscles are small, their number is probably larger in proportion than in any other known form. Moreover, just as it has been shown that the fluid in the vessels of the Nemerteans is true blood, so in the Annelida there can be little question as to the divergence of the proper blood-vessels and their contents from a water-vascular system. M. Claparède[4] agrees with the latter view; but it is no wonder that, with the scanty and uncertain materials at their disposal, other authors should have held different opinions.[5]

The examination of the circulation in such an annelid as the present is both complex and laborious, owing to the oscillatory currents in the compressed and weak animal and the opacity of the tissues; besides the ease with which all trace of vessels can be effaced by the yielding surroundings, and the diversity in the cephalic vessels—due to the remarkable changes in those bearing the lateral organs. This single type would have afforded, in this respect, material for a much more exhaustive study than it received.

Under a low power, it is noticed that at each contraction the anterior part of the body is translucent, whereas in dilation a median and two lateral trunks (which tint the body of a fine pinkish hue), separated by the attachments of the vertical muscle, are apparent. The contraction thrusts out the proboscis, and, on retraction of the organ, dilation of the three great channels again occurs. Moreover, numerous transverse

[1] *Annéles Chétopodes du Golfe de Naples*, pp. 266, 269, and 287.

[2] *Vide* the recent remarks on the subject by Professors Rolleston and Ray Lankester (*Journal of Anatomy and Physiology*, vol. xii. part iii. p. 401, and part ix. p. 591, and *Quart. Jour. of Micros. Sc.* January 1878).

[3] Brit. Annelids, *Ray Soc.* part i. pp. 80 and 114. [4] *Annél. Sedent.* p. 103.

[5] *Vide* Prof. Huxley's *Anatomy of Invertebrate Animals*, p. 239.

vessels of communication are seen laterally, especially a conspicuous one at the posterior third of each segment of the anterior region. In the posterior division of the body, again, the greenish colour of the alimentary canal is predominant on contraction of the dorsal vessels; the pinkish blush of the blood is conspicuous on their distention. In broken specimens stretched on the surface of the sand, a constant motion—by shortening and extending the body—is kept up in the segments behind the tenth.

Commencing with the dorsal vessels at the posterior end, it is found that they arise from a bifurcation of the ventral vessel. They are closely connected by a median raphe, and travel forward along the dorsal arch of the alimentary canal—receiving in each segment a large branch from the ventral, and numerous twigs from the digestive tract—till they reach the posterior part of the tenth segment, where their walls are invested by a powerful muscular layer, which enables them to perform at this part the functions of contractile chambers or "hearts." In action, under ordinary circumstances, the latter chambers dilate, and then by vigorous systole drive the blood forward in a swift stream along the single anterior dorsal vessel. The contraction is accompanied by a general movement of the body, so that the great muscles of the anterior region and others are brought into play to aid the currents, and, moreover, the proboscis is thrust out. A pretty constant current proceeds along the dorsal trunks and through the barrier at the ninth segment, even in slightly decayed specimens, though occasionally a reversion occurs. In such, the large lateral vessel, which joins the main trunk on each side immediately behind the contracted aperture, is well seen, pouring its contents inward when the current goes forward and outward, when the stream passes backward. Sometimes when the aperture remains closed and the proboscis extruded, the blood appears to pass into the ventral vessel and return to the posterior region of the body—a course quite possible through the lateral trunks just alluded to. Coursing along the anterior dorsal vessel, the current reaches the base of the snout, and terminates in a branch to each tentacle, the blood being thrown into both simultaneously with the dorsal wave forward. After the contraction drives the blood in a swift stream along each

tentacular artery, a short pause under examination, and a slight reversal occur, so that the efferent may sometimes be mistaken for an afferent vessel. In transverse and longitudinal vertical sections, a muscular enlargement is seen under each ganglion, indicating the commencement of the tentacular arteries.

The tentacular artery, a branch of the median dorsal (and best seen from the ventral surface—at its origin), passes outward next the smooth margin of the organ, and at intervals is fixed by fibrous or connective tissue bands (the dissepiments of the tentacle), which give it a wavy aspect in contraction. It sends off an extensive series of capillaries, which proceed transversely to the afferent vessel, in many cases circumferentially, that is, pass round beneath the surface of the organ. The minute vessels during life are not so rigid as in a figure, but form a net-work distinguishable only by the globules of blood as they rush past; and they are not visible until after the commencement of the papillæ. Toward the tip, the capillaries become even more distinct, and the artery breaks up into numerous branches which unite to form the vein. The latter is much larger and apparently less muscular than the artery, the current being probably aided by the proper walls of the tentacle, though chiefly by the *vis a tergo*. It lies next the papillose anterior border of the organ, and sends its current into the efferent cephalic trunk, as will shortly be explained.

During the active operations of the proboscis in boring, the tentacular vessels are shrunken, and the organs are trailed behind in the tunnel. In this condition the vessels may be observed bloodless and shrivelled, then relaxation occurs simultaneously with a forward wave, the tentacle is elongated and expanded, and by-and-by all the minute vessels are in full play; while the snout remains at rest, and the proboscis retroverted within the body. The activity of the circulation is, indeed, noteworthy. The blood rushes along the artery as rapidly as in any vertebrate (*e.g.*, a young salmon), and sweeps by an almost continuous web of capillaries into the vein. In some veins, so densely arranged are the minute vessels, that the appearance resembles a stream flowing between the layers of two transparent membranes, or pouring from a continuous narrow slit as a thin sheet into the returning current. Indeed,

it cannot be said that capillaries with distinct walls have been observed between the artery and vein. The blood streams in a thin layer from both sides of the artery, but the currents follow certain lines—no globule wanders from its track, but goes right to the vein, and the vascular lines are rendered much more distinct by an acceleration of the currents, so that such would appear to be a rudimentary system of capillaries. The advantage gained by the artery from its position on the smooth side of the tentacle, where the hypoderm is thinnest, is thus apparent; its thin streams are poured externally over both sides until they reach the vein, which is situated under the long papillæ, and has the denser layer of hypoderm between it and the water. The intermediate membrane seen in section doubtless aids in the arrangement. The pulsations of the dorsal chamber behind the ninth segment cause the tentacular artery to bulge and assume a somewhat zig-zag aspect, like the kinks of a firm india-rubber tube. They occur about seventeen times per minute, and the same acceleration makes the current in the vein flow as quickly in the opposite direction; but there is no undulation of the wall of the latter vessel. On retraction of the proboscis, the stream is likewise augmented.

All the foregoing activity of the tentacular circulation is displayed by the animal while at rest, so that the blood which formerly lent powerful aid in the functions of the proboscis is now diverted into these channels. During the various movements of the tentacles, which are generally waved to and fro in a gentle manner, the large vessels cross many times by the twisting of the slender organs. A glance at their colour in the vigorous animal, as they project with the head and anterior region out of the sand, shows their great vascularity, and indicates their importance in the aeration of the blood. Further, when they are removed, the animal thrusts out its snout and anterior region into the surrounding water, and waves them to and fro about 120 times per minute, apparently to compensate for the deprivation of its natural mode of oxygenation.

The purified blood returning from the tentacle by the vein curves forward from the base of the organ toward the snout, and constitutes the efferent vessel of the latter; so that the swift jet noticed in the cephalic trunks is mainly due to the impulse of

the great dorsal transmitted along the efferent and afferent vessels of the tentacle; hence the muscularity of the dorsal and the absence of branches in its forward course. The cephalic artery passes anteriorly to the tip of the lateral muscles in the ordinary examples, and, bending round, constitutes the vein which returns the blood to the ventral system. In a specimen in which the dorsal trunk remained distended with blood, as none passed into the injured tentacles, the currents in the cephalic vessels still existed, but their direction was uncertain. Such currents were, therefore, probably due to the wave from the ventral system, for the vessels and other tissues very readily accommodate themselves to altered circumstances.

In transverse section, the cephalic vessels lie in their special chitinous chamber quite to the inner and inferior margin of the median muscles of the snout, then in their course forward get beneath the latter, turn to their outer border, and are clasped by the external muscles, the long diameter of the vascular chamber being directed upward and outward. They are thus environed by the muscles and their chitinous septum; and while their yielding wall readily expands into the median region of the external muscle, they are sufficiently protected from undue compression. After the termination of the lateral muscles at the tip, the vessels lie to the exterior of the median muscles, and bending downward end in the cephalic vein on each side. In regard to relative position, the artery and vein are nearly parallel, and on a horizontal plane at the commencement of median muscles posteriorly, the outer chamber representing the former and the inner the latter. At this part, the vessels have a special and firm chitinous chamber beneath the median muscles, supported externally by the lateral muscles. After they are enclosed by the latter, the septum forms a firm support, while the free wall is thin and yielding. Each vessel has its proper elastic, or, it may be, muscular wall.

In those with the lateral organs developed, a curious change occurs in the cephalic circulation, since the vessels are much abbreviated and their currents modified. Instead of the long trunks above described, a short branch from the contractile ---ity passes forward by the side of the triangular nervous area ·th the median muscle, and turns backward to the sinus

behind the nerve-area. The current in these vessels exhibits none of the activity observed in the ordinary arrangement, but it is intermittent and oscillatory, and apparently due to the rythmical contraction of the muscular chamber in front of the mouth. This contraction drives the blood feebly forward; but the channel is not a rigidly defined one, since in many specimens a kind of outward spray occurs toward the tip where it joins the afferent trunk. The backward current in the latter is very feeble, then oscillates, and not unfrequently moves a little in the opposite direction. The contraction of the muscular chamber often goes on when the dorsal vessel of the body is completely at rest, so that there is no confusion. The returning blood then passes into the sinus at the base, which communicates by a median vessel (situated below the dorsal) with the space around the dorsal trunk, and probably with the ventral plexus laterally, since in some the blood can be followed along the outer branch, past the tentacular artery into the ventral system. Very complete posterior communication thus exists. In weak specimens, with rudimentary tentacles and the proboscis in a state of partial extrusion, a stream of blood occasionally proceeds from the cavity of the latter organ into the sinus or transverse vessel behind the triangular area. Simultaneous with the contraction of the dorsal vessel, again, the blood sometimes courses across the sinus, performing a curve from side to side over two chitinous bars.

The foregoing change is associated with a peculiar expansion and translucency of the terminal portion of the median muscles of the snout, apparently from a kind of atrophy, and which disappears with the absorption of the lateral organs. Moreover, in transverse section, it is seen that the chitinous arrangement in general, and especially the investment of the vascular area, as well as the vessels themselves in the anterior region of the snout, have become atrophied; indeed, all the tissues are softer, and the vertical diameter of the snout diminished. In a large example, however, with the lateral organs partially developed in January, the cephalic vessels had the ordinary arrangement, while the tips of the central muscles were diaphanous; and in a male loaded with spermatozoa at the same season, and in which the lateral organs were present, the diaphanous tapering tips

were extended forward nearly to the cuticle, and curved inward like the horns of the springbok. Both, however had been in confinement for three months. The majority of the specimens in September were small, probably because such were later in development; but it must be noted that the same arrangement occurred in large examples, while, on the other hand, some of the small presented the ordinary condition.

From the upward curve at the tail the two dorsal vessels proceed forward, under the pennate central process of the dorsal longitudinal muscles, and in close connection with the upper wall of the alimentary tract, to the anterior part of the eleventh body-segment. In transverse section, the vessels usually present the form of a double ellipse (though the form depends entirely on the degree of contraction), fixed in the middle line to a suspensory pedicle continued from the raphe of the dorsal longitudinal muscles. They are covered superiorly by the outer investment of the intestine, and in dilation expand into its yielding glandular roof. The vessel in each case has a fine structureless lining membrane, and a conspicuously barred series of striated, circular, muscular fasiculi externally, so that it somewhat resembles a trachea with coiled fibres. Lastly, an investment of connective tissue binds the vessels to each other and to the surrounding organs. As the trunks approach the tenth segment, the circular muscular fibres increase in strength, and are specially developed immediately behind the barrier; thus the great muscularity of these dilatable chambers enables them to perform a heart-like function—their pulsations ranging from fifteen to eighteen times per minute. In some views the thick coat of the vessels behind the barrier appears to have longitudinal fibres, while the elastic outer coat is much developed. At the junction of the two posterior dorsal with the single anterior vessel, again, strong longitudinal bands occur within the external circular. These soon terminate, however, and the single anterior dorsal trunk occupies a space formed by a series of strong muscular fibres—arising from the raphe between the dorsal longitudinal muscles and passing by the side of the alimentary canal. The proper wall of the dorsal vessel is quite thin at this part, so that its current probably depends on the *vis a tergo*, and its muscular

surroundings, which are remarkably dense in the ninth body-segment. The channel is thus completely under control. In the eighth body-segment the vessel is comparatively free, and its wall again increases in thickness, consisting of an external elastic layer, and an internal coat of longitudinal fibres, the latter being arranged in a very close parallel manner, and presenting quite a different appearance from the fibres of the ordinary muscles, or those of the barred circular layer of the posterior vessels. Anteriorly the dorsal trunk passes over the mouth, from which it is separated only by glandular tissue and its own sheath, and terminates in the tentacular vessels as formerly mentioned. The sheath of delicate fibrous tissue in which the trunk glides is continued into the denser chamber at the mouth.

The lateral trunks—external and internal—spring from the returning cephalic vessels, and in the first segment of the body form numerous transverse anastomoses with each other, so that a large plexus exists in connection with the proboscidian system.[1] The blood in the transverse branches is not much affected by the extrusion of the proboscis, as might, indeed, be inferred from their dorsal position. Before this *rete mirabile* terminates in the single ventral vessel at the ninth body-segment, the outer lateral—in bending inward to the median line—form slight pouches or dilatations (analogous to those of the dorsal vessels), which pour the blood backward at short intervals, and simultaneously with the forward jets of the dorsal "hearts." In observing the anterior region of the body in repose it is difficult to say in what direction the current in these vessels proceeds. It seems to disappear in contraction—through the transverse vessels, and does not go in a continuous straight stream backward. In ordinary circumstances, however, a large current flows backward in the sheath of the dorsal vessel, and thus moves in the opposite direction to that in the latter. The aspect of the whole anterior system favours the idea that it is a great vascular plexus in connection with the proboscis. On the thrusting out of the latter, an elongation of the entire region occurs (from the contraction of the strong vertical and oblique

[1] It is sometimes convenient to puncture the proboscis, and allow part of the blood to escape, so as to render the anterior vessels more evident.

muscles), and the blood is sent into the proboscis, so that the vessels just mentioned are more or less emptied, and the part becomes pale and more translucent by transmitted light. The complete action of the vascular channels, indeed, seems to take place only during the movements of the proboscis. The *rete mirabile* of this region has many homologies with the œsophageal plexus of the Nemerteans.

On transverse section it is found that the internal lateral vessels commence in front as a trunk on each side of the anterior pharyngeal region, and another soon appears in the space between the oblique and vertical muscles. Each vessel is furnished with a dilatable elastic (and probably muscular) wall, and the anastomoses formerly mentioned take place between them. About the point of attachment of the great lateral retractor muscles to the pharynx, the two internal lateral occupy a position above the latter (one on each side), and the walls are now evidently muscular—the most evident fibres being circular. Moreover, after the retractors pass out in mass to be inserted into the raphe above the ventral longitudinal muscles, the outer lateral vessels are for the time displaced. At this point is a trace of the inner lateral vessels beneath the great muscular wall of the pharynx, and a belt of blood occurs between the narrow longitudinal layer of fibres over the transverse ventral muscle, and the massive retractors of the proboscis above. The former channels show their proper walls, and the latter likewise appear to have a membranous investment. It is possible that at this part the blood pours into the proboscis. The external lateral channel soon appears again on each side between the vertical and oblique muscles, and only a little blood occurs beneath the pharynx and inferiorly at the ventral wall. At the termination of the pharyngeal exsertile region the walls of the large external lateral vessels are very muscular, their structure indeed resembling that of the dorsal trunk, while the blood in the two positions just indicated seems to be devoid of a sheath. This, however, is only apparent, as a little behind—a pair of muscular median or ventral vessels exist, stretching in section from the superior arch of the œsophagus to the base. Immediately before the great fan-shaped expansion of the muscles of the ninth body-segment, the inner lateral vessels occupy nearly the same

position, as also do the external lateral between the vertical and oblique muscles. In the muscular expansion the latter have descended near the ventral insertion of the muscles; while the former have below and then between them a large muscular mass, which appears to be in connection with the commencement of the ventral trunk beneath the narrowpart of the alimentary canal, and which has a strong bundle of muscular fibres running into each side anteriorly at the common insertion of the oblique and vertical. The external now disappear from the great fan-shaped muscular expansion and join the median or internal, which are chiefly developed inferiorly, and furnished with a powerful muscular investment. The muscular bands from the inferior arch of the alimentary canal still lie between them, and beneath the muscle is a trace of the anterior end of the ventral vessel. Lastly, the walls of the internal vessels become still more muscular, and they unite to form the single median ventral trunk, which reaches from the œsophagus above to the transverse ventral muscles beneath. The wall of the vessel is formed by a thick layer of vertical fibres, which extends from the chitinous raphe below the alimentary canal to that in the centre of the transverse muscle. In transverse section the outline of the vessel is fusiform, while the cavity is a mere vertical slit. The vessel retains a similar position throughout the posterior region of the worm, its own proper muscular coats of longitudinal and circular fibres (which are densest anteriorly) becoming conspicuous after the cessation of the special muscles in the ninth body-segment, and the degeneration of the transverse ventral muscles into rounded chitinous remnants. The vessel is held in position by various lateral fibres besides the connection—to the intestine superiorly and the raphe inferiorly—formerly alluded to. It terminates by bifurcating into the vessels which turn upward to join the dorsal trunks at the tip of the tail.

The general arrangement of the circulation in the posterior segments is as follows (taking, for example, the eighteenth segment of the region):—A large vessel proceeds outward from the ventral trunk at each dissepiment (marked externally by a deep transverse segmentation) and trends under the body-wall to the posterior part of the segment, thus necessarily passing the bristle-tufts of one side in its course. It then forms a loop,

returns to the dissepiment, and bends inward to join the dorsal vessel. When the body, however, is viewed uncompressed and in favourable conditions, a series of small branches are observed connecting the foregoing artery and vein. After the current for some time goes on with rapidity, a large branch suddenly appears—nearly opposite the bristle-tuft—in the vein, *i.e.*, in connection with the forward current, and the blood turns backward to a large sacculated chamber. A retrograde movement next takes place in the anterior part of the vessel, so that the pouch is largely distended. Then the latter chamber contracts—driving the blood vigorously forward along the vein into the dorsal trunk, and the ordinary circulation goes on as rapidly as at first. All the stages are repeated at short intervals, though they escape notice if the animal is much compressed, or unless viewed laterally. A large branch of the artery joins the vein above and below the point at which the vessel to the sac comes off, and when the chamber is in process of distention by the backward current, both pour their blood into its neck. The appearance of the bifid posterior end of the sac varies. This peculiar arrangement did not escape Dr Fritz Müller, for, in the few sentences devoted to the animal, he observes—"Rücken- und Bauchgefäss; an der Grenze je zweier Segmente der hinteren Körperabtheilung entspringt aus jedem derselben ein Seitengefäss; diese laufen neben einander nach aussen, dann geschlängelt nach hinten und enden in eine gemeinsame contractile Blase." His figure[1] (unfortunately inverted) though incomplete and not in all respects accurate, is creditable. The distinguished writer on the Annelida, Professor Edouard Grube, in his introductory note to Dr Fritz Müller's paper, also alludes to the subject, and expresses a hope that further research will be bestowed on this remarkable feature. The arrangement seems to be a provision for escaping the evils of retardation—due probably to the contraction of the dorsal vessels and the mechanism at the ninth-body segment. Further, in each segment small branches proceed (apparently from the ventral) to the alimentary wall, pass outward over it, and then turn upward to join the dorsal trunks. These intestinal vessels branch and communicate with each other on the ventral region

[1] Fig. 10, Taf. 6, *op. cit.*

of the canal (and probably also on the dorsal), and in all the minute globules of the blood enable the observer to trace them. No vessel enters the feet or lateral processes. With the exception of the larger size of a few of the lateral branches in the segments immediately following the ninth, the foregoing is the ordinary arrangement in the posterior division of the body.

At the anterior part of a regenerated tail (and this is a common condition even in the newly captured animals) each segment has a distinct vascular loop which follows the usual course, that is, proceeds a little behind the bristle-bundles and foot. By-and-by the loop only reaches the bristle-bundle; while in the terminal segments it extends as a simple and nearly straight vessel from the ventral outward and upward to the dorsal. When the tail is much contracted the circulation does not proceed quite to the tip, but passes by these short vertical branches rapidly from the ventral to the dorsal—a point of some physiological interest. The active ciliation of the intestinal tract and the thinness of the cutaneous tissues, together with the frequent movements and contractions of the region, probably also assist in the aeration and circulation of the blood. A little within the tip of the tail the ventral blood-vessel bifurcates, and bending slightly outward each division proceeds backward and upward to a point below and rather behind the anus, then curving inward, meets its fellow of the opposite side to constitute the two dorsal vessels. There is nothing like a caudal "heart" or dilation in this form.

The circulation on the whole is more difficult to unravel than in the large *Nerine foliosa*, Sars. The bright red blood in the latter is driven from the tail forward in the dorsal vessel, which sends off in each segment a trunk to the branchia, the aerated blood descending by the branch joining the ventral. There is no special provision for thrusting out the proboscis, as the animal bores with its pointed snout and muscular body. At the tip of the tail a kind of caudal reservoir is found at the junction of the main trunks. Another very evident contrast is the prominence of the cilia in *Nerine*.

The circulation has certain analogies with that in the anterior region in the Serpulidæ and Sabellidæ—where there are no distinct dorsal and ventral vessels. In the latter the purified

blood from the branchia mixes with the rest in the plexus, and then part proceeds posteriorly in the ventral vessel. There are again very interesting resemblances between the anterior vascular chamber in *Magelona* and that in *Spirographis*—even to the muscular arrangements.

Histology of the Blood.

The blood forms a coagulable pale rose-pink fluid charged with minute corpuscles, which, after extrusion, group themselves in various masses—after the manner of similar coagulable fluids. The majority of the globules are nearly equal in size, though there is considerable variety in this respect. They also exhibit molecular motions, and their outline is sometimes altered by pressure. Many are ovoid, some circular or irregularly rounded. If the blood corpuscles are minutely examined in the liquor sanguinis (*e. g.*, in the tentacle) many show a shining globule or pale nuclear structure in the centre. Besides the ordinary globules are various other bodies, some perhaps indicating the development of the globules inside a cell-wall. A minutely granular coagulum is also placed here and there amongst the corpuscles. In feeble animals the globules seem to be more distinct; and the blood in the proboscis of a dying specimen assumes a brownish-red aspect (brownish-purple by transmitted light).

The addition of a drop of strong acetic acid to a slide of fresh blood causes a very marked change. The whole field is now covered by a granular debris, and in place of groups of corpuscles, masses of much larger definite granular cells occur. The acid probably dissolves the coat of the globule, or so alters its surroundings as to permit the contents (probably fatty) to aggregate into large masses.

Perivisceral Chamber and Fluid.

Anteriorly the perivisceral chamber can scarcely be said to exist in the ordinary acceptation. The body-cavity is bounded superiorly by the great dorsal longitudinal muscles, laterally by the vertical muscles, and inferiorly by the long retractors over the transverse ventral muscles. It contains the œsophagus and short retractors. A translucent minutely granular coating pre-

senting a cellular or globular aspect occurs in the preparations on the surface of the vertical muscles in the space between the vertical and oblique, and also in the cavity of the ventral longitudinal muscles, as well as at the sides of the long retractor. Such granular cells and globules evidently subserve an important function in the economy of the animal. No perivisceral corpuscles have been noticed in this region.

Behind the ninth segment the body-cavity is considerably altered and enlarged. The chamber is rounded in transverse section and contains the alimentary canal, the dorsal and ventral blood-vessels, and the perivisceral fluid. The same cellulo-granular coating occurs on the inner surface of the vertical muscles. The perivisceral chamber is divided into two parts by the median ligament attached to the blood-vessels dorsally and ventrally. The contained fluid is perfectly translucent, coagulable and corpusculated. The corpuscles are not very numerous, are circular, oval, fusiform, or irregularly rounded, and besides are flattened. Though some small globules and granules occur, as a rule they are very much larger than the blood-corpuscles, with which they cannot be confounded. They show no trace of striæ or granulations, only a very slight cloudiness in their protoplasmic centres. In healthy animals these bodies collect in considerable masses in certain parts of the posterior region, and their great size and translucency are striking. The chamber continues to the posterior end of the body, and terminates at the tail. There is no communication with the exterior.

The absence of the perivisceral fluid from the anterior region of the body is an important feature in connection with the functions of that part. The great development of the blood-system again, and its corpusculated condition, together with a characteristic perivisceral fluid, are somewhat at variance with the views expressed by Dr Williams, who held that there existed a law "which demands that the true blood of the Annelida should be invariably fluid, non-corpusculated, because in this class the office which devolves upon the floating cells is performed in the chylaqueous fluid, where alone such cells exist." The perivisceral fluid of *Nerine foliosa*, Sars., is not more prominent than in *Magelona*, yet the blood is entirely devoid of corpuscles.

THE ARRANGEMENT OF THE AZYGOS AND SUPERIOR INTERCOSTAL VEINS IN THE THORAX. By Basil Gordon Morison, M.B., C.M.

While acting during the past winter as Demonstrator in the dissecting rooms of Edinburgh University, I was led to examine the azygos and superior intercostal veins, in order to find out on what plan they are most commonly arranged. The statistics of this inquiry are given below in a tabular form, and I have added a few conclusions which may be deduced from them. Though cases were noted in which various irregularities in distribution appeared, the venous trunks commonly presented on each side of the thorax the following arrangement:—

On the left—

(1) A vena azygos minor inferior, receiving the veins of the lower intercostal spaces.

(2) A superior intercostal vein, receiving those of *two* spaces, the second and the third, and passing across the arch of the aorta to the left innominate vein.

(3) A vena azygos minor superior draining the spaces intervening between those which supply the last two veins.

(4) A distinct small vein from the first intercostal space accompanying the superior intercostal artery, and joining the left innominate vein apart from the vein (2) which crosses the arch of the aorta.

On the right—

Only six cases could be examined, but in all these the arrangement was invariable, viz.:—

(1) A vein from the first space joining the right innominate vein or the end of the vertebral.

(2) A vein formed by veins from the second and third, or second, third, and fourth spaces, and joining the vena azygos major at the root of the lung.

The azygos major was not specially examined, but was never noticed to differ from the ordinarily accepted distribution.

The total number of cases examined was 38.

Examination of the venæ azygos minores of left side, in	23
Examination of the left superior intercostal crossing aorta, in	14
Examination of vein in first space separate from last, in	16
Examination of right upper intercostal veins, in .	6

I would draw attention to the following points.

I. Do the minor azygos veins usually join the azygos major by a common trunk or not?

In the cases examined I saw that—

(1) They joined the major separately in	10	of the	23	cases.
(2) Cases in which though each joined the major independently, there may have been a small cross branch between them before they did so, in . . .	3	„	23	„
(3) Each joined the major separately, but a small cross branch existed. In one case the connecting branch received one or two intercostal veins, in . .	3	„	23	„
(4) The minor azygos veins joined the major by a common trunk, in	7	„	23	„

Conclusion drawn.—Venæ minores usually join the major separately, and not by a common trunk. They are occasionally connected before their termination by a small cross branch.

II. As to the junction of the vena azygos minor superior with the left inferior intercostal which crosses the arch of the aorta.

(1) The connection existed in . . (The main trunk of the superior intercostal crossed the arch as usual to reach the innominate.)	9	out of	14	cases.
(2) Doubtful connection. (Imperfectly investigated), . . .	5	„	14	„

My inference is that the left superior intercostal and vena azygos minor superior usually join just before the former turns up over the aorta.

III. The dissection of the small vein passing from the first space on the left side and accompanying the superior intercostal artery, showed that—

(1) This vein was present in 11 of the 16 cases. (I believe it was not found in the remaining 5, because it was not looked for as a separate vein.)

Of these 11 cases, 4 joined the beginning of the left innominate vein above the point where the vein crossing the arch joined it; 4 joined a branch of the left innominate in the neck, (2 the vertebral, 1 the ascending cervical, 1 doubtful); 3 passed up into the neck, but the end could not be traced.

Inference.—There is a left superior intercostal vein apart from that which passes over the aortic arch. It lies in the first intercostal space, is the proper companion of the superior intercostal artery, and corresponds exactly to the right superior intercostal vein. It joins the left innominate vein, or a branch of it; the vertebral as a rule.

IV. Right superior intercostal vein drained the first space, and accompanied the corresponding artery.

It joined the right innominate vein in .	2 of 6 cases.
„ a branch of right innominate in	3 „ 6 „

(Twice the vertebral, once doubtful.)

In one case it could only be traced into the neck, no ending was seen.

So far as the cases go they show a uniform tendency in the superior intercostal vein to join the innominate vein, or a branch of it (usually the vertebral).

In 5 of these 6 cases (all in which this investigation was made), the 2nd, 3rd, and sometimes 4th intercostal veins passed to the vena azygos major by a common trunk. It seems to correspond to the branch on the left side which crosses the aorta.

I add a few remarks as to the number of intercostal spaces drained by each vein, and as to the vertebra at which the minor azygos vein usually joins the major.

A. Spaces drained—

(1) Vein of 1st space on left side drained that space.

(2) Superior intercostal vein which crosses the aorta,

drained .	2nd and 3rd spaces	in	5	cases
„ „	2nd, 3rd and 4th	„	3	„
„ „	2nd or 3rd only	„	2	„

The other cases not made out. (*i.e.* area seems to be 2nd to 4th spaces.)

(3) Minor superior usually as low as 7th or 8th space of each, ...	6	„
(4) Minor inferior drained the spaces below last named, as high as 9th space usually, ...	12	„
8th space less usually, . . .	6	„

B. Junction with major—the result of examination of the 23 cases.

Minor superior at the vertebra corresponding in number to the lowest space drained, but tending in some cases to join near, or at the vertebra next below.

Minor inferior at the vertebra corresponding to the highest space drained by it, but tending to join near or at the vertebra next above.

NOTE ON A CURIOUS HABIT OF THE *MALAPTERURUS ELECTRICUS*. By A. B. STIRLING, *Assistant Curator of the Anatomical Museum of the University of Edinburgh.*

ON several occasions the late Professor Goodsir obtained specimens of living *Malapterurus electricus* from Old Calabar, in West Africa. The specimens were forwarded to him by the late Rev. Z. Baillie, missionary on that station. The last specimens sent were received in the end of July 1864. On that date I was despatched to the town of Annan for four fish left by Mr Baillie in charge of Mr Hunter, banker.

On my arrival at the College with the fish they were found to consist of three specimens of *Malapterurus electricus* and a non-electrical Siluroid *Clarias Xenodon*. Two circular zinc baths, measuring 18 inches in diameter by 12 inches deep, with double walls and bottoms, capable of holding 2 gallons of water between their walls, and a self-regulating gas apparatus for heating, attached to each bath, were prepared for their reception. A glass vessel, 15 inches in diameter by 10 inches in depth, was placed within each of the zinc baths, and was filled with water to a depth of 5 inches. The water within the walls and bottoms of the zinc baths, as well as that put into the glass vessels, was heated to a temperature of 75 degrees, and was kept steady up to this heat by the self-regulating gas apparatus.

Two of the largest *Malapteruri* were put in one of the baths, and the smaller one along with the *Clarias Xenodon* in the other. The baths were put on a platform erected for them in Mr Goodsir's working room, and were purposely shaded from the full daylight. The fish were brought from Old Calabar in pickle bottles, and received no further attention during the voyage than changing the water once a week. No food was offered to them during the voyage, nor for two weeks after their arrival in Edinburgh. At this time—the middle of August 1864—the two largest *Malapteruri* were removed to the Botanic Gardens, Inverleith Row, and were placed in a tank in one of the hot-houses there. Both fish died in the course of the autumn or winter.

The two fish left in my charge continued to live and thrive. I called the *Malapterurus* Joe and the *Clarias* Dick, by which names they were always known afterwards. About the end of August I began to feed them with scoured worms. I began by putting a few worms in the water before leaving at night, and found they were all eaten up by next morning. I then changed my plan of feeding, by putting in the worms in the morning on my arrival at the College. In a few days I found that Dick would take a worm from my hand, coming up to the top of the water for it; he had also become very tame, and would allow himself to be touched gently with the hand.

One morning, about two hours after I had fed them, I noticed that both fish were swimming quickly round the glass vessel, Dick going first, about his own length in front, and keeping close to the glass; they had made several rounds while I was observing them, thinking they were at play, and admiring how steadily they were going. At this juncture Joe made a sudden dart forward, passing Dick, who drew up short, and vomited all his breakfast. To my disgust, Joe instantly turned, and swallowed the whole mess. On seeing this repeated several times, I mentioned it to Professor Goodsir, who also witnessed it many times afterwards; and as Joe never took live worms, we came to the conclusion that this was his natural way of procuring his food.

Joe was only 5 inches in length, but was very stout made, his body being fully an inch and a half both in breadth and thickness, and about 3 oz. in weight. He was in appearance a slow, sleek, simple-looking fellow, hiding away in the darkest part of the vessel. Dick, on the other hand, looked a formidable fish, with a large flat head, long tentacles bristling around a huge mouth, a dorsal fin reaching from the nape of the neck to the tail, which along with an anal fin of nearly equal length, and with his naturally quick movements, gave him a fierce appearance. Dick, however, was gentle and tame, allowed himself to be touched while in the water, and took worms from the hand, coming to the surface of the water for them. He ate voraciously—would swallow worms till his stomach bulged out visibly—probably to compensate in some measure for those he had to eject when he received the shocks from his companion.

As an example of Joe's power, I may mention an incident that

took place one day. Professor Kölliker and a friend called to see Mr Goodsir. On going into the room I was asked to show the fish to these gentlemen. I removed the glass vessel in which they were to a table in a good light. Dick came up and took worms from my hand, allowed himself to be touched, and was commended for his tameness. Professor Kölliker persuaded his friend, who either did not know, or did not believe, in the electrical power of the *Malapterurus*, to try and lift Joe out of the water. As I did not understand their language, I could only gather from the Professor's face that a joke was intended. The gentleman having loosened his wristband and pushed up his sleeves, proceeded cautiously and gently to capture the fish. Joe lay quiet and still, as was his usual way, his body slightly curved in a crescent form, allowing the hand to close on him loosely, when he administered such a shock as both surprised and amazed the gentleman. His hand and arm were driven out of the water as high as his own head; he seemed bewildered, to the great amusement of the onlookers.

Dick and Joe lived together for nine months. On going to feed Dick one morning, I found him lying dead on the floor. I do not know how he came to be there, but I suspect that Joe had given him one shock too much. Joe continued to live for three or four months without food. He refused to eat the worms which were put into the water, in which they might lie until they were decomposed without being touched. I regret to say that Joe's end was tragic also. The regulator of the gas had got out of order, and the result was overheating of the water, which in all probability caused the fish to leap out. I found him about three yards distant from the bath, covered with dust, from the floor on which he had been floundering about.

The two fish are preserved in the Anatomical Museum of the University.

THE DEVELOPMENT OF THE OVA, AND THE STRUCTURE OF THE OVARY IN MAN AND OTHER MAMMALIA; WITH SPECIAL REFERENCE TO THE ORIGIN AND DEVELOPMENT OF THE FOLLICULAR EPITHELIAL CELLS. By JAMES FOULIS, M.D., *Edinburgh*. (PLATES XIX., XX., XXI.)

WALDEYER'S beautiful monograph on the ovary was published in 1870. In 1872, at the suggestion of Professor Turner, I undertook a series of observations with the object of inquiring into the accuracy of Waldeyer's views as to the tubular structure of the ovary, and also of ascertaining whether Graafian follicles were formed from these tubular structures in the way described by Waldeyer and his predecessors.

The conclusions at which I arrived, as the result of my investigations, were communicated to the Royal Society of Edinburgh, by Professor Turner, on the 21st December 1874, and were published in the *Transactions* of the Society in vol. xxvii., 1875, in a paper entitled, "The Development of the Ova, and the Structure of the Ovary in Man and other Mammalia."

My chief conclusions were as follows:—The ova are derived from the germ epithelium cells, but the cells of the follicular epithelium have a different origin, viz., from the cells of the stroma of the ovary; and with reference to the tubular structure of the ovary I stated that, although I had examined the ovary of the human fœtus and new-born child, and the ovaries of many animals in various stages of development, I was unable to find any real tubular structures, and consequently was obliged to deny their existence, and that Graafian follicles are formed from such structures in the way described by Valentin, Pflüger, Speigelberg, and Waldeyer.

As I shall have to refer frequently in the course of the following paper to the views of Waldeyer on the development of the follicular epithelium and the tubular structure of the ovary, it is necessary that I should state clearly what these views really are.

According to Waldeyer, the first appearance of the ovary consists of a thickened germ epithelium investing a small outgrowth rich in cells

which projects from the interstitial tissue of the Wolffian body on its median side.

The thickened epithelium gradually forms the rudiments of the ova and Graafian follicles and of the subsequently appearing epithelium of the ovary, whilst the outgrowth itself is destined to furnish the vascular stroma of the organ.

In the embryo of fowls, Waldeyer states the interesting observation may be made as early as the fourth day of incubation, that some among the germ epithelial cells have become conspicuous by their round form, their size, and the size of their nuclei. It may be concluded from the regular arrangement of these structures and the constancy of their position that they represent the youngest primordial ova, which thus, even during embryonic life, are formed by a simple process of growth from the epithelial cells of the germ organ.

The further development of the ovary depends on a peculiar mode of growth of the superficial epithelium on the one hand, and of the vascularised stroma on the other. Certain more or less delicate processes of the connective tissue now shoot forth from the stroma, whilst coincidently the epithelium increases by the continual production of new cells. The processes then penetrate between the epithelial cells, enclosing a variable number of them, which thus, by degrees, become more and more imbedded in the vascular stroma.

Some, and sometimes many, among the imbedded epithelial cells become conspicuous by their size and the size of their nuclei, as we have already seen to occur amongst the superficial epithelial cells. Other cells remain of small size, and surround the larger cells as a kind of epithelium. The connective tissue stroma between the imbedded masses of epithelial cells constantly undergoes increase, and especially grows in between the several egg cells with their epithelial investment. Thus each epithelial ball is divided by these ingrowing vascularised trabeculæ into as many cavities as it contains egg cells.

In describing the ovary of a newly-born child, Waldeyer thus states, in reference to its tubular structure,—"One sees long branching formations in the form of tubes, anastomosing with each other, as Valentin first described, and lying separate from each other at considerable distances. They pass upwards opening with narrow mouths into the epithelium, and appear as direct tubular gland-like processes of it.

"At the time in which the tubes described by Pflüger exist, that is, as far as I can find, from the ninth month till a short time after birth, they present the structure ascribed to them by Pflüger, with the exception already mentioned, that there is as little of a membrana propria in them as there is in the primary follicles. In the tubes, and mostly in the middle of them, as Pflüger described, we meet with egg cells distinguished by their size and form, often immediately concatenated one behind the other. Whether in the tubes new egg cells are formed, I cannot decide; but I think it likely, because here, as well as on the surface epithelium, some epithelial cells may develop into egg cells."

Follicles are formed from the tubes as well as from the egg compartments, directly through the growth of interstitial tissue. At the lower end of the tube, as may be well explained from the want of a membrana

propria, interstitial tissue grows into the tubes and encloses the individual egg cells along with a portion of the not fully developed epithelial cells which surround them, and in this way primary follicles are produced.

In summing up Waldeyer thus remarks :—

"As the chief result of my investigations, it must be stated that both the egg and the follicular epithelial cells are derived directly from the germ epithelium. There is a reciprocal growth of vascular connective tissue and germ epithelium cells, in consequence of which large and small masses of the latter become imbedded more and more in the stroma of the ovary. The imbedded cells present a variety. Some of them, by simple increase in size, grow into ova, viz., primordial ova, while others keep to their original size, and by numerous divisions, at least as it appears to me, produce still smaller cells, viz., the follicular epithelial cells. A genetical distinction between primordial ova and follicular epithelial cells has consequently no existence. The germ epithelium is the common source of both."

In 1875, soon after the publication of my results, Kölliker published a short paper,[1] in which he brought forward altogether new views as to the origin of the follicular epithelial cells. He has reproduced his views in the second edition of his *Entwicklungsgeschichte des Menschen und des Höheren Thiere.* At page 971, vol. ii. of this work, he gives a drawing of part of a section of the ovary of a one to two days' old bitch, and endeavours to show that the follicular epithelial cells are derived from certain cords of cells situated in the hilus of the ovary, which he believes are derived from the Wolffian body. He says the cords of cells are continuous with the egg tubes of Pflüger, and give origin to the cells of the follicular epithelium.

In the *Quarterly Journal of Microscopical Science,* vol. xviii., Mr F. M. Balfour, of Cambridge, has lately published a most interesting paper on "The Structure and Development of the Vertebrate Ovary." This paper records observations on the ovaries of two types, viz., Elasmobranchii and Mammalia.

In Mammalia, Balfour's observations have been carried out on the ovaries of rabbits at various stages of development. He states that his results are most in accordance with those of Waldeyer, with whom he agrees in the fundamental proposition that both the ovum and follicular epithelial cells are derived from the germ epithelium, but he cannot accept Waldeyer's views of the relation of the stroma to the germ epithelium.

[1] *Verhandlung d. Phys. Med. Gesellschaft,* Wurzbürg, 1875, N. F. Bd. VIII..

The following is the summary of his observations on the Mammalian ovary:—

1. The ovary in an eighteen days' embryo consists of a cylindrical ridge attached along the inner side of the Wolffian body, which is formed of two parts,—(*a*) an external epithelium, two or three cells deep (the germinal epithelium); (*b*) a hilus or part forming in the adult the vascular zone, at this stage composed of branched masses of epithelial tissue (tubuliferous tissue) derived from the walls of the anterior Malpighian bodies, and numerous blood-vessels, and some stroma cells.

2. The germinal epithelium gradually becomes thicker, and after a certain stage (twenty-three days) there grow into it numerous stroma ingrowths accompanied by blood-vessels. The germinal epithelium thus becomes honeycombed by strands of stroma. Part of the stroma eventually forms a layer close below the surface, which becomes in the adult the tunica albuginea. The part of the germinal epithelium external to this layer becomes reduced to a single row of cells, and forms what has been spoken of in Balfour's paper as the pseudo-epithelium of the ovary. The greater part of the germinal epithelium is situated internal to the tunica albuginea, and this part is at first divided up by strands of stroma into smaller divisions externally and larger ones internally. These masses of germinal epithelium, probably sections of branched trabeculæ, may be spoken of as nests. In course of the development of the ova they are broken up by stroma ingrowths, and each follicle, with its enclosed ovum, is eventually isolated by a layer of stroma.

3. The cells of the germinal epithelium give rise both to the permanent ova and to the cells of the follicular epithelium. For a long time, however, the cells remain indifferent, so that the stages, like those in Elasmobranchs, Osseous Fish, Birds, Reptiles, &c., with numerous primitive ova imbedded amongst the small cells of the germinal epithelium, are not found.

4. The conversion of the cells of the germinal epithelium into permanent ova commences in an embryo of about twenty-two days. All the cells of the germinal epithelium appear to be capable of becoming ova. The following are the stages in the process, which are almost identical with those in Elasmobranchs:—

(*a.*) The nucleus of the cells loses its more or less distinct network, and becomes very granular, with a few specially large granules (nucleoli).

The protoplasm around it becomes clear and abundant—the primitive ovum stage. It may be noted that the largest primitive ova are often situated in the pseudo-epithelium.

(*b.*) A segregation takes place in the contents of the nucleus within the membrane, and the granular contents pass to one side, where they form an irregular mass, while the remaining space within the membrane is perfectly clear. The granular mass gradually develops itself into a beautiful reticulum with two or three highly refracting nucleoli, one

of which eventually becomes the largest and forms the germinal spot *par excellence*.

At the same time the body of the ovum becomes slightly granular.

While the above changes, more especially those in the nucleus, have been taking place, the protoplasm of two or more ova may fuse together, and polynuclear masses be so formed. In some cases the whole of such a polynuclear mass gives rise to only a single ovum, owing to the atrophy of all the nuclei but one, in others it gives rise by subsequent division to two or more ova, each with a single germinal vesicle.

5. All the cells of a nest do not undergo the above changes, but some of them become smaller (by division) than the indifferent cells of the germinal epithelium, arrange themselves round the ova, and form the follicular epithelium.

6. The first membrane formed round the ovum arises in some cases even before the appearance of the follicular epithelium, and is of the nature of a vitelline membrane. It seems probable, although not definitely established by observation, that the zona radiata is formed internally to the vitelline membrane, and that the latter remains as a membrane, somewhat irregular on its outer border, against which the ends of the follicle cells abut.

At the beginning of his paper on the mammalian ovary, in referring to my paper in the *Transactions of the Royal Society*, Balfour thus remarks :—

"In the very interesting paper of Foulis, the conclusion is arrived at that while the ova are derived from the germinal epithelium, the cells of the follicle originate from the ordinary connective tissue cells of the stroma.

"Foulis regards the zona pellucida as a product of the ovum, and not of the follicle. To both of these views I shall return, and hope to be able to show that Foulis has not traced back the formation of the follicle through a sufficient number of the earlier stages. It thus comes about that, though I fully recognise the accuracy of his figures, I am unable to admit his conclusions."

This statement of Balfour's has puzzled me very much. My recorded observations show that I carefully traced the first appearance of the follicle in the ovary of a fœtal calf of about nine inches in length, in the ovaries of kittens at birth and onwards, in the ovaries of the human fœtus of 3½ months and 7½ months, and the new-born child.

It was in my endeavour to trace the formation of Graafian follicles from the so-called Pflüger's tubes, and from the tubular structures described by Waldeyer, that I came to the conclusion no such structures of the nature of tubes exist in the ovary,

and that Graafian follicles are not formed from long tubular ingrowths of the germinal epithelium in the manner described by Valentin, Pflüger, Spiegelberg, and Waldeyer. In describing the ovary of the new-born child, Waldeyer states—"At the time in which the tubes described by Pflüger exist, that is, as far as I can find, from the ninth month till a short time after birth," &c.; and again he says, "Follicles are formed from the tubes as well as from the egg compartments," &c., and he goes on to describe the process. Now, if I have examined the ovaries of the human fœtus of 3½ months, of 7½ months, and of the new-born child, I must have both seen and traced the first appearance of the follicles. I certainly proved to my own satisfaction that the formation of follicles from tubular structures in the new-born child, as described by Waldeyer, was altogether erroneous. In fig. 21, Plate XXIX., I gave a drawing of the first appearance of the follicles in the ovary of the human fœtus of 3½ months; and in fig. 24, Plate XXX., which is a drawing of part of the ovary of a human fœtus of 7½ months, Graafian follicles in all stages of development are represented. Balfour fully recognises the accuracy of my figures, therefore, I am at a loss to understand what he means when he says I have not traced back the formation of the follicle through a sufficient number of the earlier stages.

During the last two years, in connection with the important subject of the development of the ovary, most of my attention has been directed to the question of the origin and development of the follicular epithelial cells. That it is a difficult question to decide may be concluded from the fact that there are now three different views as to their origin. All recent observers are agreed as to the origin of the ova from the cells of the germinal epithelium; the point of dispute is as to the origin of the cells which invest the ova, viz., the cells of the follicular epithelium.

Having thus briefly stated the views of Waldeyer and Balfour as to the origin and development of the ova and follicular epithelial cells, and the view of Kölliker as to the origin of the latter, and as I have continued in the investigation of the subject since my original memoir was published, I shall relate the further observations which I have made.

I think it necessary, first, to give a short account of the method of preparing ovaries for section, which I have hitherto used, especially as the reagent I chiefly employ is described by Balfour as useless.

My experience is that, on the whole, no reagent gives such excellent results as Mueller's fluid. I have used it for several years in preference to any other, for the following reasons:—It preserves the finest protoplasmic processes of cells exceedingly well. It enables us to examine, with great clearness, the outline and definition of cells. In tissues prepared in it the nuclei of cells as distinguished from their protoplasm are rendered very distinct.

Osmic acid has given me most excellent results as regards the relations of parts, but Mueller's fluid is far preferable to this or any other regent I have used in enabling me to examine satisfactorily the cellular elements of tissues.

My method of preparation is as follows:—The ovary, whole or in part, as fresh as possible, is immersed in Mueller's fluid, which should always be prepared from the best chemicals. The fluid is changed after three days. The ovary is allowed to remain at rest in this for not less than three weeks. I generally allow it to remain a month or five weeks in the fluid, by which time the cellular elements are well fixed. The ovary is then placed in water, to which a tenth part of alcohol is added. By this means the potassium bichromate is dissolved out. The ovary is then placed in pure alcohol for twenty-four hours, when it is ready for cutting into sections. Ordinary strong methyl spirits, without any resins in solution, will answer all purposes as well as pure or absolute alcohol.

In cutting sections, the ovary is removed from the spirit and placed in oil of cloves for about ten minutes. The superfluous oil of cloves is then removed by means of a piece of coarse blotting paper, and the ovary is imbedded in paraffin. The razor used in cutting should be well flooded with oil of cloves. The sections are at once placed in strong spirit, which dissolves out the oil of cloves. The spirit should be changed three times to ensure that all the oil of cloves is removed from the tissues. When immersed in glycerine for twenty-four hours or so, the sections slightly swell up, and may be then subjected to microscopic examination.

The Relation of the Ovary to the Wolffian Body.

My observations begin with the study of sections made through the body of a fœtal lamb about half an inch in length, the exact age of which I was unable to ascertain.

Such a section is represented in fig. 1, Plate XIX.

The Wolffian bodies, W.W. in section, may be recognised as two large globular masses projecting downwards and outwards from their attachment to the mesoblast on either side of the aorta (*a o*). Passing from the aorta, two large blood-vessels enter into the Wolffian bodies at their attachment. The primitive intestine (I), with its mesenteric attachment, occupies a situation almost in the middle line between the Wolffian bodies. In the bay formed by the Wolffian body and the mesentery, on both sides, the young sexual gland (O) may be seen projecting forward towards the middle line from its attachment to the Wolffian body. In section the young sexual organ appears as a triangular shaped outgrowth connected by its base to the Wolffian body. Under a magnifying power of a thousand diameters, it presents the appearance given in fig. 2.

The young sexual organ consists of a thickened germ epithelium (*g*) which caps a central core of stroma (*str*). On tracing the germ epithelium superiorly, it passes round the bay previously mentioned on to the surface of the mesentery, its cells at the same time gradually assuming the appearance of the ordinary peritoneal epithelial cells (*e*). Inferiorly, the germ epithelium may be traced gradually passing into and becoming continuous with the epithelial layer covering the surface of the Wolffian body. Tracing the peritoneal epithelium round the surface of the Wolffian body at a spot almost opposite to the young sexual gland, we meet with the lumen of a well-marked tubular structure (MD) in section. This is situated immediately under the peritoneal layer, and is Mueller's duct, formed at an early stage of development by the closing in of an inflection of the peritoneal epithelium in this situation. Mueller's duct eventually becomes the Fallopian tube in the female.

The germ epithelium (*g*, fig. 2) consists of a layer of cells arranged three or four deep. The cells do not present any remarkable variety in size. Each cell consists of a well-marked

round or oval nucleus with protoplasm around it. At this stage no cells having the characters of a primitive ovum can be detected among the ordinary germ epithelial cells.

Immediately under the germ epithelium a very fine linear structure may sometimes be seen. This appears to be of the nature of a membrana propria or basement membrane, and is formed, as far as I can make out, by a condensation or hardening of a portion of the protoplasm of the most deeply situated germ epithelial cells. It is by no means a perfect structure, mere traces of it only being occasionally seen. It may be traced in continuity with a similar structure on which the ordinary peritoneal cells lie.

The central core of stroma appears to consist for the most part of embryonic connective tissue, derived, as Waldeyer described, from the interstitial tissue of the Wolffian body. It is of mesoblastic origin. In the few sections that I have examined, I have not detected any traces of buds or processes from the walls of the Malpighian bodies of the Wolffian body passing into this young tissue. According to Balfour's observations, the main mass of the tissue internal to the germ epithelium in an eighteen days' old embryo of a rabbit consists of branched masses of epithelial tissue derived from the walls of the anterior Malpighian bodies, and numerous blood-vessels, and some stroma cells. Kölliker has also described this tissue, and, as I have already stated, believes that in older ovaries it gives rise to cells of the follicular epithelium. Balfour calls it tubuliferous tissue.

In many of my preparations of the ovaries of kittens at birth, I long ago noticed that deeply situated in the ovary near the hilus were many small tubules seen in section. They consisted of a basement membrane lined with columnar or oval cells. I noticed similar appearances in the ovaries of rabbits at birth. On comparing sections of the ovary and the testicle of the rabbit at birth, I was struck by the resemblance of these tubules in the female to the seminiferous tubules in the male; and I came to the conclusion that in the female they are the homologues or representatives of the seminal tubules of the testicle in the male. In the earliest stages of development it is impossible to say if the sexual gland will ultimately be an ovary or testicle.

Balfour has very carefully traced the origin and development

of this tubuliferous tissue, and has no hesitation in identifying it with the segmental cords (Segmentalstränge) discovered by Braun in Reptilia.[1] According to Braun, as stated by Balfour,

> "The segmental cords in Reptilia are buds from the outer walls of the Malpighian bodies. The bud from each Malpighian body grows into the genital ridge before the period of sexual differentiation, and sends out processes backwards and forwards, which unite with the buds from the other Malpighian bodies. There is thus formed a kind of trabecular work of tissue in the stroma of the ovary, which in the Lacertilia comes into connection with the germinal epithelium in both sexes, but in Ophidia in the male only. In the female in all cases it gradually atrophies and finally vanishes; but in the male there pass into it the primitive ova, and it eventually forms, with the enclosed primitive ova, the tubuli seminiferi.
>
> "The chief difference between Reptilia and Mammalia, in reference to this tissue, appears to be that in Mammalia it arises from only a few of the Malpighian bodies at the anterior extremity of the ovary, but in Reptilia from all the Malpighian bodies adjoining the genital ridge."

Balfour has given a figure, 35 B, which is a longitudinal section through part of the Wolffian body and the anterior end of the ovary of an eighteen days' old embryo of a rabbit, to show the derivation of this tubuliferous tissue from the Malpighian bodies close to the anterior extremity of the ovary. There can be no doubt that this tissue occupies a very large part of the ovarian stroma in the earliest stages of development in mammals, but it gradually disappears until, in the ovaries of kittens at birth, it is represented by a comparatively few tubules situated deeply in the ovary near the hilus. I have satisfied myself by a careful examination of the ovaries of kittens at birth and onwards that it has nothing to do with the ova or with the origin of the follicle cells. The true ovarian stroma, consisting of connective tissue, may always be traced passing upwards from the deeper parts of the ovary towards the germ epithelium, between the tubules; and it is this connective tissue alone that comes into contact with the ova, and, as I hope to show presently, gives origin to the follicular epithelial cells.

The next stage in the development of the ovary which I have lately studied is that of the ovary of a fœtal lamb about two inches in length. Such an ovary attached to the atrophying Wolffian body is represented in the drawing fig. 3.

[1] *Arbeiten a. d. Zool. Zoot. Institute*, Würzburg, Bd. IV.

For the convenience of description, the ovary may be divided into three zones—the true germ epithelium (*g*), the parenchymatous zone internal to this (*y*), and most deeply is the fibro-vascular zone continuous with the stalk or peduncle (*a*). The ovary from which this section was prepared was hardened in osmic acid, and it shows very well, as seen in the drawing, the germ epithelium as a thick (*g*), dark, rim or border passing round the whole organ, and becoming continuous with the peritoneal epithelium (*e*) on the stalk (*a*). The parenchymatous zone (*y*) consists of cells which resemble very closely the deeper cells of the germ epithelium, and have undoubtedly been derived from them. From the fibro-vascular zone numerous offshoots of vascular connective tissue pass upwards in a radiating manner throughout the whole parenchymatous zone, communicating with each other, and actually coming into contact with the germ epithelium. This part or parenchymatous zone of the ovary, as described by Balfour, becomes honeycombed by the upgrowing strands of stroma.

Under low powers of the microscope, the blood-vessels, with the blood corpuscles in them, may be seen, as in the figure, ramifying throughout the parenchymatous zone of the ovary. All these blood-vessels are derived from the main trunks that enter the ovary at the hilus. Each blood-vessel is accompanied by young connective tissue, with which it has an intimate relation. Within the meshes produced by the ramifications of this young vascular connective tissue are groups of cells derived from the germ epithelium. At this early stage of development there is no trace of a tunica albuginea. It is impossible to draw a line of demarcation between the true germ epithelium (*g*) and the subjacent parenchymatous zone. All that part of the ovary external to the fibro-vascular zone—*i.e.*, the parenchymatous zone and the true germ epithelium—may be regarded as consisting of germ epithelial cells in the act of being included in meshes formed by the ramifications of processes of vascular connective tissue, derived from the fibro-vascular zone.

The stalk of the ovary from which the central stroma of the ovary is derived proceeds from and is continuous with the tissue, which at this stage of development constitutes the remains of the Wolffian body (W). Mueller's duct in section may now be

seen as a large tube, and becomes the Fallopian tube. On comparing fig. 3 with fig. 2, both of which were drawn under the same power of the microscope, so that they might be more easily compared, one sees how enormously the young ovary has grown, and at the same time the Wolffian body has gradually atrophied until it appears in transverse section as represented in fig. 3. This change in the Wolffian body is brought about by the atrophy and gradual disappearance of the tubes which at an early stage formed its main structure. The shrunken Wolffian body now constitutes the greater part of the broad ligament.

In the ovary of a fœtal calf, about 10 inches in length, the structure is very much the same as that of the ovary of the fœtal lamb just described, but everything is in a more advanced stage of development. The germ epithelium still consists of cells arranged in a layer three or four deep, and the parenchymatous zone consists of cells derived from the germ epithelium, delicate bundles of vascular connective tissue from the central mass of stroma ramify in every direction among the cells of the parenchymatous zone. There is, as yet, no trace of a tunica albuginea, and it is not possible to draw a definite line between the germ epithelial layer and the subjacent zone. All round the ovary under the germ epithelium, groups of cells are in the act of being imbedded in meshes of the delicate young stroma. Deep in the ovary the imbedded cells present a considerable variety in size. The largest cells are situated in close relation to the central mass of stroma, and are characterised by the large size of their nuclei and their abundant protoplasm, while the cells more superficially imbedded are in various stages of development. The youngest cells are immediately under the germ epithelial layer. Some of the most deeply imbedded cells have already assumed the character of primordial ova. In each primordial ovum the nucleus becomes the germinal vesicle, and the protoplasm which surrounds it gradually forms the yelk of the ovum. These primordial ova have been derived at an early stage from the germ epithelium, and there can be no doubt that they have developed from the cells which were first imbedded in the stroma.

In fig. 4, which is part of the ovary of a 3½ months human

fœtus, we have the appearances presented by the primordial ova, P,P, situated most deeply in the stroma of the ovary. Such primordial ova are found chiefly in the situation indicated by the letter *y* in fig. 3, *i.e.*, in close relation to the central mass of stroma. Each primordial ovum consists of a central vesicular nucleus, around which is a quantity of clear or slightly granular protoplasm. In contact with the yelk or protoplasm, in each case are fusiform nuclei (*mm*) exactly similar to the nuclei in the stroma of the ovary. Superficial to these primordial ova are groups of cells (H), derived from the germ epithelium, in various stages of development. The fusiform corpuscles in contact with the yelk of the primordial ova are the centres from which the cells of the follicular epithelium are developed.

If we examine a section of the ovary of a 7½ months' human fœtus, we see that the central zone of fibro-vascular tissue is continuous with the stalk of the ovary, and numerous vascular processes of it pass upwards in a radiating manner towards the germ epithelium, and they ramify and communicate with each other, forming meshes in which are imbedded groups of germ epithelial cells. At the deepest part of the ovary, in close relation to the main mass of stroma, numerous large primordial ova are met with, and superficial to these are various sized groups of germ epithelial cells in different stages of development. A portion of such an ovary is represented in fig. 5. The germ epithelium (*g*) is seen as a well-marked layer consisting of columnar or oval cells, for the most part arranged one or two cells deep. They vary in size; some are oval, others round, and here and there we meet with specially large individuals, P.P., which present the characters of primordial ova. The germ epithelium passes round the whole ovary, dipping into and lining the furrows and clefts which lie between the irregularities of the surface of the ovary. At this stage the tunica albuginea is a well-marked layer of the ovarian stroma, immediately under the germ epithelium on which the latter rests.

Below the germ epithelium are groups of cells, H, H, H, derived from the germ epithelium. Such groups may be seen in many situations in the act of being shut off by the stroma from the deeper cells of the germ epithelium; while deeper in the ovary other cell groups may be seen in a more advanced stage

of development. These latter were derived from the germ epithelium at an earlier stage, and are now composed of cells gradually assuming the characters of primordial ova. All the germ epithelial cells in a nest are potentially ova.

The stroma, STR, consists of very vascular connective tissue, in which are numerous fusiform cells. The processes of the stroma may be seen arching round the groups of cells immediately under the germ epithelium. This youngest stroma is the forerunner of the tunica albuginea. By the constant imbedding of germ cells from the germ epithelium, the latter seems to become gradually exhausted in its production of new cells to take the place of those already imbedded, until at last it is reduced to a single layer of cells, and then the young stroma immediately under it becomes much more marked as the tunica albuginea. In the human child at birth onwards the germ epithelium consists of a single layer of cells resting on a well-marked tunica albuginea. This single row of germ epithelial cells has been termed by Balfour the Pseudo-Epithelium.

In an ovary of the human fœtus of 7½ months, the germ epithelium varies in thickness. Here and there the cells are two or three deep, but in the greater part of its extent it consists of a single row of cells. In examining a series of sections, such as fig. 5 represents, we often meet with specimens in which the germ epithelium has been partially or entirely stripped off from the subjacent tunica albuginea. In such places it is of the greatest interest to examine the youngest connective tissue in the act of imbedding the germ epithelial cells.

This tunica albuginea, when first formed, consists of a very young connective tissue, and fine processes of it in the form of an undifferentiated protoplasm, in which nuclei are visible, may be seen passing upwards between the germ epithelial cells, as the first step towards imbedding them. In some situations where the germ epithelium has been entirely stripped off, small groups of germ epithelial cells may be seen surrounded by this jelly-like or undifferentiated protoplasm. This jelly-like tissue, in which a few small fusiform nuclei are seen, is undoubtedly the youngest form of connective tissue, and it is derived from the older connective tissue, of which the tunica albuginea consists.

In other specimens we see jelly-like processes of the youngest

connective tissue passing up from the tunica albuginea through among the cells of the germ epithelium, completely enclosing them in groups. In fig. 18 the letters R, R, point to this jelly-like tissue enclosing the groups of germ cells, *q*, *q*. What we see in fig. 18, as indicated by the letters R, R, is in reality the cut surface of an entire capsule or tunic. The whole group of the germ epithelial cells (*q*, *q*), is actually contained within the capsule of jelly-like tissue derived from the young tunica albuginea.

Below the tunica albuginea (STR) in fig. 18, we see groups of cells or cell nests (H, H, H), which have been undoubtedly derived from the germ of epithelium in a similar manner at an earlier stage of development. In the microscopic examination of sections of the ovary, we must always endeavour to picture to ourselves the actual condition, viz., that which exists in the living ovary. Now, there can be no doubt that the numerous cell nests in the whole egg-bearing part of the ovary, which are more or less globular in form, have been derived from the germ epithelium in the way I have described. When once a large cell nest is formed in this way, it may be broken up or subdivided into smaller nests by a continuation of the same process. From the wall of the first formed capsule jelly-like offshoots pass in among the included germ cells, and by their continued growth the germ cells become separated from each other, and the whole cell group becomes subdivided into small egg-containing meshes of stroma. The cell groups when first formed are often very small, appearing to contain but three or four germ epithelial cells. Such small cell groups are seen in great numbers imbedded in the young jelly-like stroma immediately under the germ epithelium. Wherever this young jelly-like tissue proceeds fusiform, or elongated-oval, nuclei are to be seen in its substance.

The Origin and Development of the Follicular Epithelial Cells.

The ovaries of kittens at birth and onwards are exceedingly well suited for studying the relation of the germ epithelium to the stroma of the ovary, and also for the study of the origin of the follicular epithelial cells.

In fig. 6 (Plate XX.) we have represented a part of the ovary of a kitten about two weeks old. The germ epithelium (*g*, *g*),

consists of a layer of cells three or four deep. Among the germ epithelial cells there is a great variety as to size and form; some are oval and columnar, others round or spherical; while others are conspicuous by their size and the size of their nuclei, and they stand forth prominently among the ordinary germ epithelial cells. These latter are primordial ova, P. P. P. Each consists of a central large vesicular nucleus, and around the nucleus is a quantity of clear or slightly granular protoplasm.

In some sections of the ovary of a kitten at birth, I have lately observed some very curious appearances among the cells of the germ epithelium. These appearances are shown in figs. 8, 9, 10, 11. The germ epithelium (*g*) consists of the ordinary oval or columnar cells. A young tunica albuginea is present in these sections, and the germ epithelium (*g*) rests upon it. The outermost row of germ epithelial cells are on the same level, and clear protoplasm fills up the clefts between the nuclei, as shown in fig. 8. Numerous long club-like processes (*n*, *n*), are seen projecting considerably above the level of the germ epithelial layer. These processes consist of clear protoplasm. In the club-like extremities no nucleus can be detected, but in some instances I have observed a few fine granules in them. Sometimes we may trace the thin tail-like processes down between the germ epithelial cells as far as the tunica albuginea, and there they appear to be continuous, with long, fine processes of connective tissue, which are offshoots of the ovarian stroma, as shown in fig. 15. In fig. 9, one of the long processes (*n*), ending in a club-like extremity, is seen. In the nob-like end of this process a distinct vacuole exists. In figs. 9, 10, some of the nob-like ends have been broken across. In fig. 11 small bud-like processes (*n*) of protoplasm are seen sprouting up between the nuclei of certain germ epithelial cells. In the great number of instances, it appears to me that these club-like processes spring from the protoplasm surrounding the nuclei of certain germ epithelial cells; while in other cases it would appear as if they were the terminal ends of long connective tissue processes of the ovarian stroma which have grown up between the germ epithelial cells. It is not unlikely that the latter appearances are deceptive. There can be no doubt, as seen in fig. 11, that some of the buds spring directly from the protoplasm of the germ epithelial cells. In

many instances certain ordinary germ epithelial cells may be seen with long tail-like processes of protoplasm, which pass downwards into the tunica albuginea. At the extreme left of figs. 8 and 10 two such germ epithelial cells are represented.

I hope that future investigations may clear up all doubt as to the nature of these long club-like processes. They present a very remarkable appearance under the microscope. Although I have examined a very large number of sections of ovaries of kittens at birth, I have never before observed such appearances; but I can quite understand that such delicate outgrowths might be easily broken off in preparing and cutting sections of the ovary.

Examined under high powers of the microscope, there can always be seen around each large primordial ovum (P, fig. 6) a thin capsule of a jelly-like material, in the substance of which, in section, are seen two or three fusiform or elongated oval nuclei, (*m*, *m*, *m*). Between the capsule and the yelk or protoplasm of the primordial ovum no cell or other structure can be detected. The capsule lies close in contact with the yelk substance of the primordial ovum. The nuclei are not *within* the capsule, but lie imbedded in the substance of the latter, as represented in fig. 26 (Plate XXI.) It is a very remarkable and interesting observation that every large primordial ovum among the ordinary germ epithelial cells on the surface of the ovary presents the appearances just described. This nucleated capsule is always present, and there can be no doubt that it is a special arrangement for the nourishment of the ovum contained within it. The capsule is always found in close relation to the youngest connective tissue stroma, and the nuclei in it when first formed are exactly like the nuclei which exist in the youngest connective tissue in all parts of the stroma.

In some specimens of the kitten's ovary, when the tunica albuginea is formed, numerous primordial ova may be seen resting on this young connective tissue stratum, among the ordinary germ epithelial cells, and in each case a more or less delicate nucleated tunic in close contact with the yelk can be detected. In the human fœtal ovary of 7½ months and in the child at birth exactly similar appearances may be observed.

In fig. 6 the tunica albuginea is not yet formed, although there are evident traces of it. In this specimen of the ovary the large primordial ova lie in close relation to the ends of bundles or strands of young connective tissue, which may be followed down into the deeper parts of the ovary where they are discovered to be processes of the general stroma. These bundles of young connective tissue are in reality offshoots from meshes of the general stroma. The cut surfaces, as in section, of such meshes (STR) may be seen surrounding large groups of developing germ epithelial cells (H, H, H), which were imbedded at an earlier stage of development.

Below the germ epithelial layer (*g*, *g*), all round the ovary, we meet with various sized cell nests (H, H, H). In the kitten's ovary these cell nests are mostly of an elongated or oval form. Many of the cell nests are in connection superiorly with the deeper cells of the germ epithelium. They have not yet been completely cut off from the germ epithelial layer by the offshoots of young connective tissue, which eventually form the tunica albuginea. The strands of connective tissue between the cell nests are in reality the cut surfaces of the walls of the meshes which enclose the cell nests. These elongated cell nests still in connection with the germ epithelium superiorly are Pflüger's egg tubes. He supposed they were long tubes filled with developing germ cells. They are simply cell nests formed by the growth of stroma around certain of the germ epithelial cells in the usual way. The germ epithelial cells, when included in meshes, do not grow downwards into the ovarian stroma; but as the stroma grows around the cells they enlarge, and the whole group expands generally in a direction upwards and outwards in the line of least resistance. The whole ovary enlarges by the outward growth of its stroma, and by the expansion outwardly of the numerous cell nests which make up the greater part of the organ.

In my original paper I carefully described the changes which the imbedded germ epithelial cells in the egg clusters or cell nests undergo in passing into primordial ova. When an individual germ epithelial cell in the germ epithelial layer grows into a primordial ovum, the nucleus becomes spherical and vesicular. It presents a fine limiting membranous wall. Around the nucleus there is gradually added a large quantity of the proto-

plasm which gives bulk to the young ovum (see P, P, fig. 6). The great change in the size of the cell is brought about by the addition of such a large quantity of protoplasm to that which originally existed around the nucleus. In the cell nests, as the imbedded germ epithelial cells grow into primordial o·a the nuclei become spherical and vesicular, and there is gradually added to the nuclei that protoplasm which forms the yelk of the young ova. From whence comes all this material to form the yelk substance of the primordial ova? Without doubt, it is supplied by the vascular young connective tissue with which such developing ova are always in close relation. Among the cells of the germ epithelium around each primordial ovum (P, P, P, fig. 6) may generally be detected the nucleated capsule which I have already described. So generally is this the case, that I am forced to the conclusion that no ordinary germ epithelial cells develop into primordial ova until the jelly-like processes of the stroma come into intimate contact with them in such a way as eventually to enclose them in capsules or tunics, in the substance of which are the nuclei from which the future follicle cells are developed. The primordial ovum is not produced before the follicle, nor is the follicle developed before the ovum. Now, what takes place in connection with the development of the primordial ova among the germ epithelial cells on the surface of the ovary also takes place in connection with the development of the germ cells imbedded in the stroma of the ovary.

Waldeyer, in his description of the formation of the Graafian follicles, states that in the cell nests some, and sometimes many, among the imbedded cells become conspicuous by their size and the size of their nuclei, other cells remain of small size, and by numerous divisions produce smaller cells, which form the follicle cells. Connective tissue then grows into the cell nests, enclosing the eggs along with the not fully developed epithelium, and in this way Graafian follicles are produced.

Balfour, in describing the formation of the follicles in mammalia, says some of the cells in a cell nest, instead of passing from primitive ova into permanent ova in the way he has described, do not undergo those changes, but become smaller (by division) and arrange themselves round the ova and form the follicular epithelium. So that, according to these two observers,

the eggs are formed first, and the follicle cells then arrange themselves around them. In-growths of stroma then enclose the eggs with the follicular epithelium. The germ epithelium is the common source of both the eggs and the follicular epithelial cells. The view I hold is this. All the ova are derived from the germ epithelial cells, but the follicle cells are derived from, and are parts of, the ovarian stroma. As the result of my observations, I have come to the conclusion that the cells which nourish the ova, and the tissue from which that nourishment is secreted, are parts of the general vascular stroma of the ovary. From the beginning of the development of the ova these two tissues are in intimate relation to each other, and progress, hand-in-hand, so to speak, during the nourishment and development of the ova. The follicle cells are formed from the nuclei in the capsular tunic of the developing ova. As soon as a primordial ovum becomes conspicuous by its size, at the same time we detect the first trace of a Graafian follicle around it. The jelly-like capsule, with its nuclei, around each developing ovum, is the first trace of the Graafian follicle.

I shall now proceed to describe the drawings which I have made in support of my views.

Figures 7, 12, 13, 14, 16, 17, are all portions of the ovary of a two or three weeks' old kitten.

In fig. 7, the germ epithelium (*g*) (pseudo-epithelium, Balfour) rests on the young tunica albuginea, STR. Delicate strands of connective tissue (STR) are seen passing upwards and becoming continuous with a jelly-like capsule (R), which encloses several large germ epithelial cells. In the substance of the capsule are seen two fusiform nuclei, *m*, *m*. Certain delicate processes of the capsule appear to pass inwards among the developing germ epithelial cells.

Figure 12 is a portion of the pseudo-epithelium (*g*) from the same ovary resting on the young tunica albuginea. A single large primordial ovum (P) is represented as being enclosed in a capsule (R, R), in the substance of which are two fusiform nuclei (*m*, *m*). Between the letters R, R, the capsule is cracked, and the broken ends are quite separate from each other. The capsule closely invests the young ovum, and is in intimate relation to the subjacent connective tissue.

Figure 13 is a portion of the pseudo-epithelium of the same ovary. To the left of the figure a primordial ovum (P), with its nucleated capsule, is seen; while to the right of the figure an empty capsule (R), with a crack in it, is observed. The crack in the capsule is close to the fusiform nucleus, *m*. Such empty capsules in the pseudo-epithelium are frequently seen. In cutting the section, the ovum has apparently been knocked out of its tunic, which now remains, looking like a ring standing up among the ordinary germ epithelial cells.

Figures 14, 16, 17, are portions of the pseudo-epithelium of the same kitten's ovary. In each figure a large primordial ovum (P) is seen; around each is the usual nucleated capsule. Strands of stroma (STR), which are part of the walls of meshes enclosing large cell nests (H) below the tunica albuginea, may be traced in each case, in direct continuity with the capsules which invest the primordial ova. I call particular attnetion to these figures.

Figure 15 is a drawing of two delicate strands of stroma which were seen passing up from the deeper parts of the ovary to the germ epithelial layer. The ends of such strands appear to pass in among the cells of the germ epithelium. In numerous instances I have seen long processes of the ovarian stroma passing through the germ epithelial layer, projecting in the form of loops beyond the level of that structure. The figures which I have thus described represent only a few of similar appearances I have lately observed; but I am of opinion that by themselves they afford sufficient evidence of the truth of my view, viz., that the nucleated capsules which invest primordial ova are parts of the ovarian stroma and constitute the first trace of the Graafian follicles.

The nourishment and the development of the germ cells in the cell nests in the stroma are carried on in an exactly similar manner. First of all, as already described, small and large groups of germ epithelial cells become imbedded in jelly-like capsules derived from the ovarian stroma immediately under the germ epithelial layer. As this process of imbedding goes on, the first formed cell groups or nests become deeper and deeper imbedded in the ovarian stroma. Not every germ cell in the cell nest develops. Only those cells which become completely invested by the nucleated capsules may be considered as permanent

ova. From the walls of the mesh of stroma enclosing a large cell nest there grow in among the included germ cells jelly-like processes of the ovarian stroma, just as we saw takes place among the germ epithelial cells on the surface of the ovary. These processes of undifferentiated protoplasm completely invest certain of the germ cells, which then rapidly advance in development to the stage of primordial ova. Wherever these processes of young stroma grow, in the substance of them fusiform nuclei appear, and these latter are thus brought into intimate contact with the yelk substance of the young developing eggs. Many of the cells in a cell nest atrophy and disappear. In studying the cell nests I have frequently seen groups of cells whose protoplasm appeared to be fused together, presenting the appearance of one large protoplasmic mass in which were several nuclei, the whole mass being surrounded by a nucleated capsule. From the ovary of a child two years of age, I have a section in which six distinct germinal vesicles are noticed in the centre of one large protoplasmic mass, while fusiform nuclei of the ovarian stroma indent the mass of protoplasm all round its periphery.

The development of the follicle cells from the nuclei of the ovarian stroma immediately in contact with the yelk of the primordial ova is a subject of the greatest interest, and I shall now proceed to describe what I have traced out during my observations.

An ordinary germ epithelial cell consists of an oval or columnar nucleus, with protoplasm round it, as represented in figure 20. In the act of becoming a primordial ovum it swells up, the nucleus becoming a sharply defined vesicular body, spherical in form, while within it a spot appears. The nucleus becomes the germinal vesicle of the ovum. Around the nucleus there is gradually added protoplasm to form the yelk substance of the ovum (fig. 21).

As the ovum becomes larger, immediately outside the yelk substance, and in contact with it, a distinct tunic or capsule may be seen investing it (figs. 22, 23). Nothing in the form of cell or nucleus is to be detected between the capsule and the included ovum. These two objects are in most intimate relation from their first appearance. The capsule consists of a jelly-like or undifferentiated protoplasm, in which fusiform

nuclei are visible. These nuclei at first are always fusiform in outline, and lie flat against the ovum, but in the substance of the capsule.

The first evidence of development which I have noticed is as follows:—The nuclei at first appear like solid fusiform rods, as in fig. 24 *m, m*. As they develop they swell out, becoming vesicular, and within them a distinct spot or nucleolus appears (figs. 25, 26, *m, m*.) At this stage they often indent the yelk substance of the ovum, as I described in my original paper. The nuclei divide, as represented in figs. 26, 27, *x, x*, and continue to swell out, sometimes producing deep indentations in the yelk of the ovum. External to these dividing nuclei, as represented in fig. 27, *x*, a portion of the original capsule remains, and, without doubt, forms the membrana propria folliculi. When first formed around the ovum, the follicle cells present the appearance of little vesicular nuclei, spherical in form, and surrounded by protoplasm, and within each a spot or nucleolus can be seen, while outside the follicle cells the membrana propria folliculi (fig. 28 *u*) is a well-marked structure. During the time this development of the follicle cells is going on, the ovum itself is developing, gradually becoming larger, and distending the follicle in every direction.

What I have now described can be seen by any one who will carefully examine sections from the ovary of a two or three weeks' old kitten.

Balfour says (page 430):—"An examination of the follicle cells from the surface, and not in section, demonstrates that general resemblance in shape of the follicle cells to the stroma cells is quite delusory. They are, in fact, flat, circular, or oval plates, not really spindle-shaped, but only apparently so in section." With this statement I cannot agree.

In section, the nuclei from which the follicle cells originate, without considering the form these eventually assume, are *always at first* of a fusiform shape. Looked down upon from above, they appear as elongated oval bodies, somewhat flattened against the ovum. As they develop, they undergo the changes in form I have described. When the primordial ova are young, and comparatively small, they are few in number and very rarely spherical in form; but when the ova are large, they all become

spherical and vesicular, and numerous around the yelk substance inside the membrana propria folliculi.

Both Waldeyer and Balfour state that the follicle cells are formed by division from certain of the germ epithelial cells.

Do these observers mean to imply that these cells first divide, and become either flat, circular, or oval plates, and then, lastly, spherical bodies, as they "arrange themselves" round the ovum to form the follicle? How do they "arrange themselves"?

I venture to state that neither Waldeyer nor Balfour have carefully traced out the steps in the development of the follicle cells from their first appearance to their last stage, or they would not have overlooked the fact that the nuclei from which the follicle cells are developed are at *the first* always minute fusiform bodies like the nuclei of the stroma cells. They are at first much smaller than the germ epithelium cells. As they develop they become larger and larger, not smaller and smaller as these two observers state, until they at last form a row of comparatively large spherical nuclei, with protoplasm round them, around the young ovum. Compare figures 23, 24, 25, 26, 27, 28, with figure 31. We thus see how the small nuclei grow until they become large spherical bodies, such as represented by the letter T in figure 31.

In the ovary of a cat about six months old, a cell nest presents a very beautiful object for study. Such cell nests are seen in fig. 19, H, H, H. Each ovum in the nest is now of large size, and around each the follicle cells are in various stages of development. In fig. 30 we have the appearance of a portion of a cell nest. The ova are all of large size; each is enveloped in a capsule of clear protoplasm, in the substance of which are nuclei of various forms. Some of the nuclei appear to be cut across, as represented in fig. 29; around such a nucleus the protoplasm may be traced in processes dipping in between and passing around two contiguous ova. In other cases the nuclei may be seen dividing, as at x, at the lower part of the figure. I know of no appearances in the ovary which seem to me to prove so conclusively the origin of the follicle cells from the stroma cells of the ovary, as those we observe in the case of a ripe Graafian follicle just about to burst to liberate the ovum.

Fig. 31 is a carefully-prepared drawing of part of the wall

and the follicle cells of such a Graafian follicle, from the ovary of an adult cat. The follicle cells, T, are large spherical bodies, in which the nuclei are at once conspicuous by their size and vesicular nature. A well-marked membrana propria (*u*) is seen in this particular specimen, and it serves to define the wall of the follicle cells.

Immediately outside the membrana propria, the cells in the wall of the stroma mesh have been converted into bodies exactly similar to the true follicle cells within the membrana propria, and among them we can detect many large fusiform cells in the act of swelling out into similar spherical bodies. At a greater distance from the membrana propria the mesh consists almost entirely of large fusiform cells, which gradually become more and more like the ordinary cells of the stroma farther away from the membrana propria. The cellular tissue outside the membrana propria is very vascular in the case of the ripe Graafian follicle, and the swelling up of the cells of the stroma outside the membrana propria into spherical bodies, exactly like the follicle cells, appears to be a provision to enable the follicle to rupture more easily than if the tissue had been fibrous. Such ripe Graafian follicles, with the appearances I have now described, afford, in my opinion, most conclusive evidence of the similarity of origin of the cells within and without the membrana propria folliculi. They are both derived from the ordinary cells of the connective tissue stroma of the ovary.

General Conclusions.

All the ova are derived from the germ epithelial cells. In the development of the ovary small and large groups of the germ epithelial cells become gradually imbedded in the ever-advancing stroma. Germ epithelial cells do not grow downwards into the substance of the ovary. The ovarian stroma constantly grows outwards, surrounding and imbedding certain of the germ epithelial cells. As these latter increase in size, and as the stroma thickens around them, the whole ovary becomes enlarged. Pflüger's tubes in the kitten's ovary have no existence as such, but are appearances produced by long groups of imbedded germ epithelial cells, many of which groups are not completely cut off from the germ epithelial layer by the young ovarian stroma. Such groups

of germ epithelial cells, in various forms, are met with in all ovaries, but have no importance whatever as tubular structures. In the human child's ovary numerous furrows or clefts between irregularities of the general surface are met with. Sections through these furrows and clefts produce the appearance as if the germ epithelium (pseudo-epithelium, Balfour) passed downwards into the ovary in the form of tubular open pits, as was described by Waldeyer and his predecessors. No real tubular structures from which Graafian follicles are formed exist in the Mammalian ovary at any stage of its development. Graafian follicles are formed only in one way from the beginning of the ovary to the end of its existence.

The youngest connective tissue of the stroma, in the form of offshoots of jelly-like protoplasm, surrounds and imbeds large and small groups of germ epithelial cells. A single germ epithelial cell may be completely surrounded by this young connective tissue. When this takes place the germ epithelial cell rapidly grows and becomes a primordial ovum. Each individual cell in a group of germ epithelial cells, surrounded by the young ovarian stroma, shows a similar tendency to become a primordial ovum. All the groups of developing germ epithelial cells or cell nests in the ovary are broken up into still smaller cell nests by the ever-advancing young connective tissue, until, at last, individual cells in the cell nests become completely surrounded by the youngest connective tissue. When an individual germ cell becomes surrounded by the young connective tissue, at the same time, and as part of the process, the Graafian follicle begins to be formed. Wherever the young jelly-like connective tissue appears, in its substance nuclei, generally fusiform at first, make their appearance. These nuclei may be always seen in contact with the yelk substance of the primordial ova. The follicle cells are derived from the nuclei which lie in contact with the protoplasm or yelk substance of the developing ova. This takes place in all parts of the ovary wherever cell nests are formed. The follicle cells thus originate from the cells of the ovarian stroma, and not from the germ epithelial cells. In the Mammalian ovary at birth the most advanced ova are met with deep in the ovary, and not in passing from without inwards, as described by some observers. In a ripe Graafian follicle the stroma cells outside the membrana

propria folliculi become converted into cells exactly similar to the true follicle cells, and it is possible to trace the ordinary stroma cells outside the follicle through all stages of development into cells resembling the follicle cells, the observation affording a most conclusive proof of the origin of the follicle cells from the ordinary cells of the stroma.

Explanation of Plates XIX., XX., XXI.

The same letters have been employed to mark corresponding structures in the whole series of figures :—

a, Stalk or peduncle of the ovary; *d*, bloodvessels; *e*, peritoneal epithelium; *g*, germ epithelium; H, egg clusters or cell nests; I, primitive intestine; *m*, fusiform nuclei in contact with primordial ova; *n*, club-like processes of protoplasm among the germ epithelial cells; P, primordial ova; *q*, groups of germ epithelial cells in the act of being enclosed in meshes of the youngest jelly-like connective tissue; R, the youngest jelly-like connective tissue; T, follicular epithelial cells; *u*, the membrana propria folliculi; *x*, fusiform nuclei dividing; *y*, the deepest part of the parenchymatous zone of the ovary; *ao*, aorta; CH, chorda dorsalis; MD, Müller's duct; STR, stroma of the ovary.

All the figures have been carefully drawn by the aid of the camera lucida. In all my investigations I have used Hartnack's instrument with No. 3 ocular. In figures 1 and 2, R. & J. Beck's 2-inch lens was employed. In figure 19, Swift's one-sixth lens was used, but in all the other figures R. & J. Beck's one-tenth immersion lens was employed.

Fig. 1. A section through the body of a fœtal lamb, about half an inch in length, showing the Wolffian body (W), Müller's duct (MD), and the young sexual gland (O).

Fig. 2. A highly-magnified drawing of the young sexual gland (O), in last figure, to show the relation of the germ epithelium (*g*) to the ordinary peritoneal cells (*e*), and to the central core of stroma (STR).

Fig. 3. A section through the ovary and Wolffian body of a fœtal lamb about two inches in length, to show the relation of the stroma of the ovary to the germ epithelium and to the parenchymatous zone (*y*).

Fig. 4. A portion of the ovary of a human fœtus of 3½ months, to show the primordial ova (P) and the fusiform nuclei (*m*) in contact with them, from which the follicle cells are developed.

Fig. 5. A portion of the ovary of a human fœtus of 7½ months, to show the germ epithelium (*g*), cell-nests (H), primordial ova (P), and ovarian stroma (STR).

Fig. 6. A portion of the ovary of a two weeks' old kitten, to show the germ epithelium (*g*), primordial ova (P), fusiform nuclei, from which the follicle cells are derived (*m*); cell-nests (H), and the ovarian stroma (STR).

Fig. 7. A portion of the ovary of a two weeks' old kitten, to show the germ epithelium (*g*), and a group of primordial ova (P), enclosed in a nucleated capsule of jelly-like young connective tissue (R) derived from the stroma (STR).

Fig. 8. A portion of the ovary of a kitten at birth, to show long club-like processes of protoplasm (*n*), projecting above the level of the ordinary germ epithelial cells (*g*).

Figs. 9, 10, 11. Portions of the same ovary as the last to show the same appearances.

Fig. 12. A portion of the germ epithelium (*g*) of the ovary of a two weeks' old kitten, to show a large primordial ovum (P) enclosed in a nucleated capsule (R), consisting of young jelly-like connective tissue derived from the stroma (STR).

Fig. 13. A portion of the same ovary, to show a primordial ovum (P) in its capsule, and alongside of it is an empty capsule (R), the ovum having tumbled out.

Fig. 14. A portion of the same ovary, to show a primordial ovum (P) in its nucleated capsule, which latter is in intimate relation with processes of the ovarian stroma (STR).

Fig. 15. Long processes of the ovarian stroma, which may be traced up as far as the germ epithelial cells.

Figs. 16 and 17. Portions of the ovary of a two weeks' old kitten, to show primordial ova (P), among the germ epithelial cells (*g*) in their capsules, which are in connection with long processes of ovarian stroma (STR). These latter are derived from the meshes (STR) enclosing cell nests (H).

Fig. 18. A portion of the ovary of a human fœtus of 7½ months, to show the germ epithelial cells (*g*), the cell nests (H), and the young ovarian stroma (STR) or tunica albuginea on which the germ epithelium rests. Also, groups of germ epithelial cells (*g*) in the act of being enclosed in a nucleated capsule (R) of the youngest connective tissue derived from the tunica albuginea.

Fig. 19. A portion of the ovary of a six months' old cat, to show the cell nests (H), the ovarian stroma (STR) in its relation to the tunica albuginea, and the pseudo-epithelium (*q*).

Fig. 20. A germ epithelial cell, consisting of a central oval nucleus with protoplasm around it.

Fig. 21. A germ epithelial cell developing into a primordial ovum (P).

Fig. 22. A primordial ovum (P) in its capsule, in the substance of which fusiform or elongated oval nuclei (*m*) are seen.

Fig. 23. The nucleated capsule.

Fig. 24. A large primordial ovum (P) with its nucleated capsule, to show the first appearance of the solid rod-like nuclei (*m*).

Fig. 25. A large primordial ovum (P), to show the nuclei (*m*) gradually becoming vesicular.

Fig. 26. A nucleated capsule, to show the division (*x*) of the nuclei (*m*).

Fig. 27. The division (*x*) of the nuclei (*m*), and the first appearance of the membrana propria folliculi.

Fig. 28. To show the first appearance of the follicle cells (T) and the membrana propria folliculi (*u*).

Fig. 29. A transverse section through a vesicular nucleus in the substance of the capsule of a primordial ovum. Processes of the protoplasm of the capsule pass in between contiguous primordial ova.

Fig. 30. A group of large primordial ova from the ovary of an adult cat, to show the first appearance of the Graafian follicle cells which are developed from the nuclei (*m*) in the capsule of each primordial ovum.

Fig. 31. A portion of a ripe Grafiaan follicle, to show (in section) the follicle cells (T), the membrana propria folliculi (*u*), and the conversion of the ordinary stroma cells (STR) into cells exactly similar to the follicle cells within the membrana propria.

NOTES ON THE DISSECTION OF A NEGRO.

By Professor TURNER, M.B., F.R.S.

EARLY in the winter session we received into the Practical Anatomy Rooms of the University the body of a Negro, twenty-five years of age, who had died of phthisis. He was born in the British West Indies, and had acted as a ship's cook for some years. His facial configuration, colour of the skin, and crisp, short, curly hair, betokened a pure Negro, without admixture of white blood. The abdominal and thoracic viscera had been removed in *post mortem* examination before the body was removed to the rooms.

As one does not often have the opportunity of making a dissection of one of the dark-coloured races, I arranged that the head and neck and limbs should be distributed amongst senior students, and requested them to note any peculiarities in the soft parts which might come under their observation. I am indebted to Messrs Benjamin Wainewright, L. Prinski Scott, E. S. Scott, W. H. Dobie, and J. Dunlop Dunlop for noting the following departures from the usually described arrangement of parts.

Muscular system.—The facial muscles of expression were well developed. The *platysma myoides* was very distinct; it covered the side of the face below the zygoma from the front of the ear to the symphysis of the lower jaw, and was inserted into the zygoma; it joined the depressor anguli oris and the levator anguli oris. The posterior belly of the *omo-hyoid* arose from the outer half of the under surface of the clavicle, and not at all from the upper border of the scapula. The *sterno-thyroid* was inserted by a pointed slip into only the upper end of the oblique line on the outer surface of the ala of the thyroid cartilage. The *semi-spinalis colli* received processes of origin from the spines of the 7th cervical and 1st and 2d dorsal vertebræ; it did not take origin from the articular processes of any of the cervical vertebræ, probably on account of the great development of the multifidus spinæ in this region.

A *musculus transversus nuchæ* was present, but its attachments

were not ascertained; it passed at its inner end under the trapezius. The *superior constrictor* had, in addition to the origins usually described, some fibres proceeding from the tendon of the tensor palati internal to the hamular process; a considerable number of the upper fibres of the muscle turned round its upper free border, where it stretched from the pterygoid origin to the posterior median raphe, and then spread out like a fan in the soft palate, blending with the deep fibres of the palato-pharyngeus, between the insertions of the levator and tensor palati. These fibres, although apparently usually referred to the deep fibres of the palato-pharyngeus, yet appeared to be integral parts of the superior constrictor.

On each side the *pectoralis minor* was not only inserted into the coracoid process, but its tendon gave off an expansion which blended with the capsular ligament of the shoulder joint. It formed a strong cord-like structure in the capsule, which was traced as far as the tuberosities of the humerus, where they bounded the commencement of the bicipital groove. The right *brachialis anticus* had its origin divided into a superficial mass, which arose from the anterior surface of the shaft of the humerus below the insertion of the deltoid; and a deep mass which arose from the lower third of the anterior surface of the shaft of the humerus. Both the superficial and deep portions united on a common tendon of insertion into the coronoid process, but from the deep portion a distinct muscular slip proceeded, which ended in a tendon that was inserted into the outer side of the tubercle of the radius. The coronoid origin of the *flexor sublimis digitorum* was by a distinct muscular bundle which pursued an independent course for two inches before it joined the humeral head of origin. The *flexor longus pollicis* gave off a muscular slip above the pronator quadratus, which united with the flexor profundus digitorum immediately below the anterior annular ligament.

In each lower extremity the following variations occurred:— A muscular slip about three inches long arose from the inner border of the *pectineus* and joined the tendon of the adductor longus. A well-defined *musculus accessorius ad musculum accessorium* arose by two fleshy bellies from the back of the bones of the leg. The inner belly sprang from the inner border of the tibia a little below the middle of the shaft; the outer

belly from a corresponding spot in the shaft of the fibula between the origins of the peroneus brevis and the flexor longus hallucis. The two bellies united at an acute angle, superficial to the deep muscles and vessels, and formed a fleshy belly, which ended in a tendon that passed under cover of the internal annular ligament between the tendon of the flexor longus hallucis and the posterior tibial nerve; in the sole it joined the anterior part of the musculus accessorius. The *peroneus brevis* had in addition to its usual insertion a separate slip into the tubercle on the outer surface of the os calcis. The *fourth lumbrical* muscle was absent. In the right limb, in addition to the above varieties, the *plantaris* had two distinct heads and fleshy bellies; the one arising from the line leading to the external condyle, the other from the posterior ligament of the knee joint superficial to the external condyle.

We may now proceed to inquire if similar variations from the usually described arrangement of these muscles have been seen in the white races.

All anatomists are familiar with variations in the amount of development of the platysma myoides, more especially with the distribution and distinctness of the fasciculi situated on the face. The clavicular origin of the posterior belly of the omo-hyoid has also frequently been observed and recorded. Some years ago I pointed out[1] that about 5 per cent. of the subjects dissected in the practical rooms of the University possessed a clavicular origin of the posterior belly of this muscle. Variations in the extent of attachment of the sterno-thyroid to the thyroid cartilage are occasionally seen. Slips of origin of the semi-spinalis colli from the vertebral spines are sometimes seen. The musculus transversus nuchæ is not uncommon, and I may especially refer to F. E. Schulze's memoir[2] on this muscle for descriptions and figures of various forms which it exhibits.

Anatomists are quite familiar with variations in the insertion of the pectoralis minor. Portions of the tendon of this muscle have been seen by John Wood,[3] Gruber, De Souza and myself,

[1] On Irregularities of the Omo-hyoid muscle.—*Edinburgh Medical Journal*, May 1861.

[2] Musculus transversus nuchæ ein normaler Muskel am Hinterhaupte des Menschen. Rostock, 1865.

[3] *Proc. Roy. Soc. Lond.* June 21, 1866.

passing over the upper surface of the coracoid process to blend with the coraco-acromial ligament, or with the capsular ligament of the shoulder.

W. Gruber has described a two-bellied origin of the brachialis anticus, and he and Führer[1] have pointed out that it may have an attachment to the radial tuberosity. The independence of the coronoid origin of the flexor sublimis is evidently a step towards that still greater differentiation described by Wood and Macalister, in which the index portion of the muscle arose as a separate muscle from the coronoid process. I have elsewhere recorded[2] the frequency with which the flexor longus pollicis is connected by an intermediate tendon with the flexor profundus digitorum.

I am not aware that a slip from the pectineus to the adductor longus has previously been recorded. The accessory muscle to the musculus accessorius is not uncommon. In my memoir "On Variability," above referred to, I have described not only specimens of this muscle, but other examples of accessory muscles situated in the region of the inner ankle, and other anatomists have also recorded cases. The existence of two bellies to the plantaris, one arising from the posterior ligament of the joint, has also been seen in the white races. The insertion of a portion of the tendon of the peroneus brevis into the os calcis is evidently uncommon.

Vascular system.—The *superior profunda* artery arose from the posterior circumflex. The *superficialis volæ* arose on a level with the lower third of the radius. The *deep palmar arch* formed an elliptical loop-like arrangement, owing to a splitting of the radial opposite the second metacarpal space into two vessels, which reunited with each other opposite the fourth space. From the anterior vessel arose two of the palmar interosseous arteries, whilst the third arose from the arch after the two vessels had reunited. From the posterior vessel all the recurrent branches arose. From the internal aspect of the left ulna an osseo-cartilaginous process projected, from the summit of which a fibrous band passed down to the carpus in proximity to the

[1] Quoted by Macalister in his catalogue of Muscular Anomalies.—*Trans. Roy. Irish Acad.* 1872.

[2] On Variability in Human Structure.—*Trans. Roy. Soc. Edinb.* 1865.

pisiform bone. Under this band a branch of the *anterior interosseous* artery, which ran downwards along the inner surface of the shaft of the ulna, passed to anastomose with the carpal branch of the ulnar artery.

The variations in the superior profunda and superficialis volæ arteries are well known. The splitting of the radial artery into an elliptical ring is evidently rare, as no such case is described by Richard Quain in his classical work on the arteries. The presence of an osseo-cartilaginous process from the ulna in conjunction with a peculiar branch of the anterior interosseous artery is, I believe, for the first time described.

Spinal nervous system.—There were two *small occipital* nerves, the smaller of which arose from the second cervical, and was distributed to the scalp behind the ear, whilst the larger arose from the first and second cervical nerves, and was chiefly distributed to the pinna of the ear. The *cutaneous* branches of the *posterior divisions* of the upper six *dorsal* nerves pierced the trapezius 1½ inch from the dorsal spines, instead of close to these spines as is usual. Each *ulnar* nerve arose by two heads, one from the inner, the other from the outer cord of the brachial plexus. The duplication of the small occipital nerve is very common, and the passage of the upper dorsal cutaneous nerves through the trapezius between 1 and 2 inches from the spine I have frequently observed. The double origin of the ulnar nerve is much rarer. It had not before been met with in the course of my experience, and I do not find any reference to it in the anatomical works that I have consulted.

Although it might appear as if the anomalies of structure in this negro were numerous, yet they were not more abundant than one sometimes sees in the bodies of white persons. They were, however, in excess of those seen by Mr John Wood in the body of a Negro which he dissected (*Proc. Roy. Soc. Lond.* June 15, 1865).

ON THE EFFECTS OF CHLOROFORM, ETHIDENE, AND ETHER ON BLOOD-PRESSURE: BEING THE THIRD PROVISIONAL REPORT OF THE COMMITTEE ON ANÆSTHETICS TO THE SCIENTIFIC GRANTS COMMITTEE OF THE BRITISH MEDICAL ASSOCIATION. By JOSEPH COATS, M.D., WILLIAM RAMSAY, Ph.D., and JOHN G. M'KENDRICK, M.D., *University of Glasgow.*

THE Committee have been engaged since their last report,[1] chiefly in investigating the condition of the blood-pressure in animals under the influence of chloroform, ethidene, and ether.

In the report of a Committee[2] appointed by the Royal Medical and Chirurgical Society, to inquire into the uses and effects of chloroform, and published in the *Transactions* for 1864, vol. xlvii., there is a very excellent but brief record of the state of the blood-pressure under chloroform and ether. The instrument used in these experiments was the hæmadynamometer of Poiseuille, which consists of a U-shaped tube, with mercury in the bend. One limb of the tube was connected with the femoral artery, and the rise of the mercury in the opposite limb indicated the blood-pressure. By means of this instrument the Committee were enabled to report that on administering chloroform there is first a transient rise of the blood-pressure, after which there is a gradual but not a regular fall. They also noticed that when the force of the heart was reduced by the chloroform to the full extent, the respiration of fresh air was at once followed by a rise of the mercury. In regard to ether, it was found that the primary rise in pressure is greater and more constant than with chloroform, and that the depressing effect is very slight, or may be altogether absent.

In our experiments we have been able to amplify these results, and, by means of more perfect instruments, to obtain more exact

[1] *Journal of Anatomy and Physiology*, Pt. II. p 224.

[2] The members of this Committee were T. B. Curling, Thomas Bryant, Samuel Cartwright, Arthur Farre, George G. Gascoigne, George Harley, Prescott Hewett, F. W. Mackenzie, William Marcet, Charles H. Moore, James Paget, William O. Priestley, Richard Quain, Francis Sibson, R. Dundas Thomson, Charles West, Septimus W. Sibley, George W. Callender, John Birkett—Mr Clover assisting.

records. We have used a very complete kymograph, made by Rudolph Rothe of Prague,[1] by means of which the variations in the column of mercury produced by the pulsations in an artery are written on a sheet of blackened paper, which is carried round by a clock-work arrangement. A sheet of paper eight feet long is adapted to the machine, and as three or four lines of tracing can be taken at different levels on the same sheet, a continuous tracing may be obtained of 24, 32, or even more feet. But further, the sheets can be changed in a few seconds, and so it is possible to take tracings of almost any length.[2] The instrument has also appliances by which the time may be recorded in seconds, half-seconds, or otherwise, immediately beneath the tracing of the blood-pressure. Lastly, there are two arrangements by which the exact times of administering and of discontinuing an anæsthetic can be marked. In this way we have obtained records of experiments on rabbits and dogs, those on dogs being of much the greater value.

In the case of the rabbit there is one fact of considerable interest, which seems to be deducible from these records. When the animal is not fully under chloroform, any fresh administration causes the most remarkable variations of blood-pressure, with retardation of the heart's contractions. There is frequently a sudden dip in the pressure to the extent of 40 mm. out of a total of 110 mm., and in the next few contractions there is a very rapid rise up to the former level, to be succeeded by another sudden dip. This occurrence followed so uniformly in certain stages of chloroform narcosis, on every approximation of a sponge containing the agent even for a few seconds to the animal's muzzle, that it was regarded as probably reflex. This is rendered probable by the fact that ammonia vapour applied to the nostrils of a rabbit causes stoppage of the heart's action.[3] When chloroform is given continuously, these variations gradually cease, and there succeeds a regular and gradual fall of pressure down to zero if the agent is pushed. It was noticed

[1] See Dr M'Kendrick's *Outlines of Physiology*, p. 358.

[2] In one case, a tracing 150 feet long was obtained.

[3] See Professor Rutherford's paper in *Journal of Anatomy and Physiology*, vol. viii. p. 283. "Cause of the retardation of the pulse which follows artificial or voluntary closure of the nostrils of the rabbit."

that in one or two instances ethidene produced sudden variations in pressure similar to those of chloroform, but that ether did not. Our experiments were not fully prosecuted on rabbits in regard to the more permanent effects of these two agents; but it may be said in general that ether seemed to have no influence on blood-pressure, while ethidene reduced it to a considerable extent, but not to total extinction like chloroform.

Turning to our experiments on dogs, the very first observation made was an exceedingly striking one. The animal used was a black retriever, six or seven months old. Chloroform was given, and during deep anæsthesia a canula was introduced into the carotid and connected with the kymograph. By the time connection with the kymograph was established no chloroform had been given for about two minutes. On first making the connection the pressure registered 104 mm., which may be regarded as nearly normal. But now, without any fresh dose, the pressure suddenly fell to zero with a remarkable retardation of the heart. Each pulsation had a height of 9 mm.,[1] and a duration of a second and a half. After this the pressure rose with remarkable variations, equal to 13 to 16 mm., referable to the respiratory movements. It is to be remembered that the animal had at this time nearly recovered from chloroform, as evidenced by the high initial pressure, and this sudden fall of pressure is apparently reflex in character, the heart being perhaps more liable to such influences under the conditions present. A fresh administration of chloroform at this time led to a fresh variation of pressure somewhat resembling those already referred to in the case of rabbits. On continuing the administration, all irregular variations were abolished, and the pressure gradually fell, but the agent was not in this instance pushed very far. During recovery from this administration, 70 seconds after the chloroform had been removed, and when the pressure had risen to 66 mm., there was, without any apparent cause, an occurrence somewhat like that at the outset, but less in degree. The pressure fell to 20 mm., and the heart's pulsations became infrequent,

[1] It will be understood that the figures given represent the column of mercury raised, or the difference in level of the mercury in the two limbs of the U-shaped tube. This will always be double the distance from the point at which the mercury in the two limbs is level.

each pulsation taking one and a half seconds. This continued for six beats, when the pressure rose slowly to 100 mm., with recovery of the frequency of the pulsations.

Ether administered to this dog produced little effect on the pressure; if anything, improved it. There was slight diminution of pressure when the animal was struggling and howling.

Ethidene was given while the animal was still to some extent under the influence of ether. The pressure gradually but very slowly fell, and under repeated doses reached a minimum of 20 mm. The agent being still continued, the pressure began to rise, and had reached 28 mm., when it was removed. Subsequently ethidene was again given, and after prolonged and constant use the pressure was brought down to 7 mm., when the administration was stopped. It should be noted that all this time the respiratory movements were uninterrupted.

The same dog was used for a further set of experiments, which were prosecuted after a short interval, during which the animal partially recovered.[1] The pressure at the beginning of this series registered 110 mm., and the variations of pressure with respiration were well marked. Chloroform being given, there was an immediate fall of pressure, with considerable variations and reduction in the frequency of the heart's pulsations. The pressure remained about 70 or 80 mm. for about half a minute, and then there was a very rapid fall, with great slowing of the pulsations till the heart almost ceased. There was an interval of three seconds between two of the pulsations, of nine seconds between the next two, and of six seconds between the next, the pressure in these intervals being *nil*. The chloroform was removed when this rapid fall occurred. During this period the respiration continued. The pulsations were now resumed, but between each pulsation the pressure was minus, and the pulsation only raised the mercury 10 mm. generally to the basement line, while the beats occupied about one and three-quarter seconds. After twenty-nine of these pulsations, the breathing stopped, while the pulsations went on regularly as before. After a few seconds, artificial respiration was used by alternately compressing

[1] During the whole of these experiments anæsthesia was complete from beginning to end, and the partial recovery referred to was indicated by a return of blood-pressure to the normal.

the chest and leaving it to expand. This being prosecuted for thirty seconds, spontaneous respiration was resumed, and the pulsations became more marked, having a rather higher excursion than before, but still returning to a pressure of zero between each two pulsations. This continued for about forty-two seconds, when the pressure began to rise, and this went on continuously till in one hundred and sixty seconds a height of 100 mm. was reached.

We have dwelt in some detail on this last experiment because we regard it as one of unusual interest and importance. It is to be remembered that this animal got chloroform in the usual way, by a cloth saturated with the agent being held over his mouth and nose. He received no overdose, and the administration only lasted seventy seconds. As bearing on at least one mode of death under chloroform, the relation of the heart's action to respiration is of particular significance. The blood-pressure is enormously reduced, and the pulsations have become so infrequent as to be virtually ineffective, yet respiration continues. But respiration stops forty seconds after the heart has resumed, the pulsations being still, however, so ineffective, that the pressure is even minus.[1] We believe that the legitimate inference to be drawn is that the stoppage of respiration was due not directly to the chloroform, the inhalation of which had ceased for about forty-eight seconds. It seems likely that the failure of the heart in the first instance, and the insufficiency of its subsequent pulsations, were the cause of the failure of respiration. In such a state of the circulation the respiratory centres would probably be insufficiently supplied with blood, and be consequently liable to cease acting. In this case, if death had occurred it would only apparently have been due to the failure of the respiration; the primary failure being that of the heart. To what extent this may apply to human cases we do not venture to speculate.

We now resume consideration of this set of experiments. The animal was allowed to recover considerably, and the pressure had reached 106 mm. when ethidene was administered. There was a slow but steady fall of pressure, the lowest point being reached

[1] That there was no fallacy here was determined by testing the instrument afterwards.

in about a hundred and twenty seconds, when the height was 36 mm. Continuing the administration, there was a slight rise up to 50 mm., when the administration was discontinued. During the administration, the cardiac pulsations were regular in frequency, with slight variations in the height of the waves, probably depending on respiration.

It will not be necessary to give our further experiments in such detail. In one set we kept up artificial respiration by means of the pump,[1] administering the anæsthetics by passing the air through a Wolff's bottle containing the respective agent. In these experiments chloroform promptly reduced the pressure, which began to recover almost immediately on its removal. On continuous administration, the pressure fell much more gradually than by the ordinary method, and the lowest point reached still represented a considerable pressure, about 65 mm. The initial pressure was 132 mm. Ethidene was begun at a pressure of 80 mm., the recovery from the chloroform depression being incomplete. After prolonged use there was a fall to 54 mm. On removal a gradual recovery ensued, which attained to 80 mm. Ether was then given, when again a slight fall in pressure ensued.

The next experiment is a somewhat interesting one, offering in a certain sense the converse of one already narrated. The same animal was used as in the last experiment; the tracheal tube was left in, and the animal breathed through it. The anæsthetics were administered by holding a cloth soaked with the agent over the mouth of the tube. Chloroform was given, and there was an almost immediate fall of pressure; but the fall was gradual, and in two hundred and thirty-four seconds had reached 28 mm., when the chloroform was stopped. The respiration ceased just after the chloroform had been removed. Artificial respiration was at once resorted to, but in spite of this the heart ceased beating twenty-one seconds after. It is remarked, however, that although there were no indications of the heart's pulsations in the tracing, the pressure was maintained at 28 mm., and it is just possible that there may have been slight pulsations too feeble to be recorded. The pause of the heart continued for

[1] The apparatus for artificial respiration used in the Physiological Laboratory, University of Glasgow, is the double-piston pump, made by Rudolph Rothe, of Prague, and figured in his price-list.

twenty-one seconds, and the pulsations were then resumed very feebly and irregularly. The pressure rose gradually to 46 mm., when a spontaneous respiration was given; then with long intervals spontaneous respirations were resumed. Artificial respiration was then stopped, as it was not required.

In this observation, it seems undoubted that the respiration failed first. The rapid failure of the heart is a remarkable circumstance, especially when the comparatively high pressure is considered. It is possible that the use of artificial respiration may have had to do with it. The respirations before they ceased were shallow, and though the air in the lungs was saturated with chloroform, little of it would find its way into the blood in the very limited respiratory movements. The introduction of artificial respiration would at first force the saturated air rapidly through the lungs, which would be vigorously inflated, and thus a large amount of chloroform would be introduced into the blood.

After the animal had recovered from this experiment ethidene was given. There was a fall of pressure, but, though administration was continued in frequently-repeated doses for nine minutes, the blood-pressure only fell to 38 mm., and there was no failure of respiration. Before the ethidene was removed the pressure had risen to 60 mm.

In this animal the pneumogastrics were now cut, and the observations repeated both with and without artificial respiration. It cannot be said that any essential difference was apparent in the results. The pressure fell both with chloroform and ethidene, but the fall was perhaps not so rapid or so great as under other circumstances. While artificial respiration was used, ethidene and chloroform were successively pushed to a very great extent, the Wolff's bottle being heated to facilitate the evaporation of the agents. Yet the blood-pressure was not reduced to the lowest even with this treatment, and in the case of ethidene it even began to rise under it. The effect on respiratory variations in pressure was remarked during these experiments In the case of ethidene, even when the agent was given to the fullest extent, the respiratory curve, though very much diminished, did not entirely disappear. In the case of chloroform the respiratory curve disappeared completely, and that

shortly after the commencement of administration. The cardiac pulsations in the case of chloroform became scarcely perceptible, the pressure, however, not falling below 40 mm. With ethidene in the same circumstances, the cardiac pulsations remained of nearly normal amplitude.

As a result of the whole set of experiments with this dog, it may be said that the heart showed throughout a remarkable state of vigour. It only exhibited signs of giving way on one occasion, and in that case the blood-pressure was maintained at a comparatively high position. On the other hand, respiration failed during the administration of chloroform very readily. In these respects the animal contrasts with the former one. It is quite obvious also that on these occasions when the breathing ceased the animal would almost certainly have died, but for the use of artificial respiration.

In some further experiments which we made with another dog, using Fick's kymograph,[1] a more remarkable result was obtained. Both respiration and heart had stopped under the use of chloroform, but by means of artificial respiration (by the pump) there was ultimate recovery, although the pulsations of the heart had ceased for a considerable time. In this case there could not be any feeble pulsations keeping up the circulation at a slow rate, as was supposed to be possible in a former case, because Fick's arrangement registers very accurately the slightest variations in the pressure produced by the heart's action. In the case of this dog also it was observed that several times, after a period of shallow respirations, the breathing stopped for a brief interval, the heart beating with considerable vigour. As respiration had ceased, no more chloroform was admitted to the blood, and after a time the respiratory movements returned. So much was this the case, that difficulty was experienced in killing this dog with chloroform; and this was only effected by administering it by artificial respiration after the spontaneous movements of respiration had ceased. By artificial respiration an additional quantity was introduced, and the heart soon succumbed.

These facts are of considerable importance, as they show the varying effects of chloroform in the same animal at different times. At one period respiration and the heart failed nearly

[1] The form shown in Dr M'Kendrick's *Outlines*, fig. 93, p. 357.

at the same time. At another respiration failed, and the heart, being still vigorous, was able to carry on the circulation till the chloroform had been sufficiently eliminated to allow of the recovery of the respiration.

The facts obtained from these researches seem to us to warrant the following conclusions:—

1. Both chloroform and ethidene administered to animals have a decided effect in reducing the blood-pressure, while ether has no appreciable effect of this kind.

2. Chloroform reduces the pressure much more rapidly and to a greater extent than ethidene.

3. Chloroform has sometimes an unexpected and apparently capricious effect on the heart's action, the pressure being reduced with great rapidity almost to *nil*, while the pulsations are greatly retarded, or even stopped. The occurrence of these sudden and unlooked-for effects on the heart's action seems to be a source of serious danger to life, all the more that in two instances they occurred more than a minute after chloroform had ceased to be administered, and after the recovery of the blood-pressure.

4. Ethidene reduces the blood pressure by regular gradations, and not, so far as observed, by these sudden and unexpected depressions.

5. Chloroform may cause death in dogs either by primarily paralysing the heart or the respiration. The variations in this respect seem to depend to some extent on individual peculiarities of the animals; in some the cardiac centres are more readily effected, in others the respiratory. But peculiarities in the condition of the same animal very probably have some effect in determining the vulnerability of these two centres respectively, and they may both fail simultaneously.

6. In most cases respiration stops before the heart's action; but there was one instance in which respiration continued while the heart had stopped, and only failed a considerable number of seconds after the heart had resumed.

7. The use of artificial respiration was very effective in restoring animals in danger of dying from the influence of chloroform. In one instance its prolonged use produced recovery even when the heart had ceased beating for a considerable time.

8. Under the use of ethidene there was on no single occasion

an absolute cessation either of the heart's action or of respiration, although they were sometimes very much reduced. It can therefore be said that, though not free from danger on the side of the heart and respiration, this agent is in a very high degree safer than chloroform.

9. These results confirm and amplify those stated in a previous report, to the effect that ethidene does not compromise the heart as does chloroform. By the method of experimentation then employed, the effect on the blood-pressure could not be determined, and altogether the results here obtained are more exact and unequivocal.

It may be added that, since last report, ethidene has been given to a number of patients of all ages, with results which may be described as satisfactory. Given freely at first, it produced anæsthesia as rapidly as chloroform, and the effect could readily be kept up by comparatively small subsequent doses. The only drawback is that in some cases it produced vomiting; but it is not determined that it does so more frequently than chloroform, over which it has the further advantage of producing less excitement, and being more agreeable to the patients.

Iso-butyl chloride was given to three patients, but it produced considerable excitement, and proved an imperfect anæsthetic. It has therefore been abandoned.

The Committee intend next directing their attention to the influence of anæsthetics on the pulmonary circulation, and to their action on various kinds of protoplasm.

The Committee will give an account of the previous history of ethidene chloride in the next number of this Journal.

UNUSUAL ABNORMALITY OF THE ARTERIES AT THE BASE OF THE BRAIN. By Stanley M. Rendall, *Assistant Demonstrator of Anatomy, University of Edinburgh.*

The vertebral arteries of either side joined as usual to constitute the basilar, which, immediately after its formation, divided into two trunks, and again uniting formed a loop. The loop, which was about two lines in length, was situated near the lower border of the pons Varolii.

The main artery now ran forwards, giving off the inferior cerebellar and transverse arteries of the pons, also the two superior cerebellar arteries, and then terminated in two small branches in the position of the posterior communicating arteries.

Each internal carotid, after giving off the ophthalmic branch, varied in its arrangement on the two sides. The left carotid gave off first the posterior cerebral artery; this was joined by the small communicating branch from the basilar, and then ran on to its normal distribution in the posterior lobe of the cerebrum. The next branch was the middle cerebral, which was quite normal both in size and course. The terminal portion of the left internal carotid, having the direction and appearance of a large anterior cerebral artery, ran forward to the anterior extremity of the locus perforatus anticus, where it divided into two equal branches; one of these, in direction and appearance the termination of the vessel, continued onwards in the usual course of the left anterior cerebral artery. The other division took a sharp turn to the right, and then, after a short transverse course of about two and a half lines, another sharp turn forwards, so as almost to form two right angles, where it constituted the anterior cerebral artery of the right side.

The right internal carotid artery resembled the left in giving off both the posterior and middle cerebrals. These two arteries had the usual size and distribution; the former received the communicating branch from the right basilar. As the functional right anterior cerebral was derived from the left internal carotid, the branch of the right carotid which represented that artery was very slender, and joined the functional vessel where it passed forwards in the great longitudinal fissure.

NOTE ON THE DISTRIBUTION OF THE ANTERIOR TIBIAL NERVE ON THE DORSUM OF THE FOOT. By D. J. CUNNINGHAM, M.D., *Senior Demonstrator of Anatomy, University of Edinburgh.*

IN Ruge's article upon "The Development of the Muscles of the Human Foot,"[1] I notice a point in connection with the distribution of the anterior tibial nerve on the dorsum of the foot, which is not mentioned in any of our text-books. It is that in some cases this nerve supplies twigs to the dorsal interossei muscles. According to Ruge, Rüdinger was the first to investigate this matter.[2] The latter author describes four interosseous twigs proceeding from the anterior tibial nerve—one from the *inner division* of the nerve for the first or innermost intermetatarsal space, and three from the *outer division* of the nerve for the three outer spaces. Before reaching the spaces these interosseous nerves give twigs to the tarsal joints, and then run forwards on the dorsal interossei to reach the metatarso-phalangeal joints, in which they end. He distinctly states that each interosseous nerve supplies twigs to the muscle upon which it lies.

Ruge only admits the presence of two of these interosseous nerves —those in the two inner intermetatarsal spaces. He has never been able to trace the *third* further forward than to the base of the metatarsus, and he regards the fourth as being frequently wanting. He does not believe that twigs are given by these nerves to the interossei muscles as a constant occurrence, although he allows that the second interosseous nerve sometimes gives a twig to the second dorsal interosseous muscle. He accounts for this peculiarity by looking upon the second dorsal interosseous muscle in these cases as being a compound muscle—receiving an accessory head from the extensor brevis digitorum. The nerve filament which goes to it, then from the anterior tibial, is for the supply of these extraneous fibres.

During last winter session two dissections were made in the Practical Anatomy Rooms of this University, which showed the innermost interosseous branch of the anterior tibial nerve; and in both twigs were seen proceeding from it into the substance of the first dorsal interosseous muscle. This induced me to prosecute the inquiry further, and with the aid of Messrs Sheridan Delépine and Thomas Fulton, students of medicine, I have made three special dissections of the anterior tibial nerve on the dorsum of the foot. In two of these the *fourth or outermost interosseous nerve* was evidently absent. Both Ruge and Rüdinger have stated that this is frequently the case. In the single instance in which it was present we were unable to trace it further forwards than the base of the fifth metatarsal bone. The *three inner interosseous nerves* were found in all the dissections, but

[1] *Morphologisches Jahrbuch*, 1878.

[2] Die Gelenknerven des Menschlichen Körpers, Erlangen, 1857.

in one instance the *third nerve* did not proceed further forward than the base of the metatarsus. In two cases the *third nerve* ran forwards in the intermetatarsal space to the metatarso-phalangeal joints, but it gave no twigs to the subjacent interosseous muscle. In each instance we were able to detect twigs proceeding from the *second nerve* to the second dorsal interosseous muscle, and in two of the dissections muscular filaments were given by the *first nerve* to the first dorsal interosseous muscle.

Two branches are usually given by the inner division of the anterior tibial nerve to the innermost intermetatarsal space. Of these, one at once passes downwards, in company with the arteria dorsalis pedis, to the plantar aspect of the first tarso-metatarsal joint, in which it apparently ends. The other branch usually divides into two, and these are carried forward in the intermetatarsal space to the first metatarso-phalangeal joint. It is from the latter that the muscular twigs proceed. The *second* interosseous nerve and the *third* nerve, when it reaches the intermetatarsal space, both, in like manner, give plantar branches which pass downwards alongside of the corresponding perforating arteries, and which are evidently destined for the supply of the plantar aspect of the tarso-metatarsal joints.

The fact of the second and sometimes the first dorsal interosseous muscle receiving twigs from the anterior tibial nerve does not in any way affect their relation to the external plantar nerve. Their nervous supply is simply derived from the two sources.

A LOOP-LIKE BIFURCATION OF THE EXTERNAL CAROTID ARTERY. By Professor Turner.

Loop-like bifurcations of the chief arteries of the body are by no means common; but during the present winter three cases have been observed in my Practical Anatomy Rooms:—one in the deep palmar arch of the Negro described on p. 382; one in the basilar artery of the case described by Mr S. M. Rendall in the communication on page 397; and the one I am now about to note in the external carotid artery.

The subject was an adult male. The left external carotid had its customary origin, and ascended into the parotid gland. It gave off in the usual manner the superior thyroid, lingual, and facial branches, and then bifurcated just below the angle of the jaw into two almost equal-sized arteries, which united a little below the temporo-maxillary joint so as to form an elongated loop. From the place of re-union the internal maxillary, temporal and transverse facial arteries arose, together with a small branch, to the parotid gland. The posterior auricular artery arose from the posterior limb of the loop, but the anterior limb gave off no branch. The occipital artery arose from the external carotid, prior to the bifurcation, opposite the interval between the origins of the superior thyroid and lingual. The ascending pharyngeal arose close to the commencement of the external carotid.

ON THE ORGAN OF BOJANUS IN ANODON. By MARCUS M. HARTAG, *The Owens College, Manchester.*

THE view that the blood of the molluscs mingles with water in the organ of Bojanus (or, for shortness, the kidney) seems prevalent. I trust to show that it is a mistaken one, at least as far as *Anodon* is concerned.

In this animal, as is well known, numerous pores perforate the wall of the foot and communicate with its blood lacunæ. The cilia, fringing these pores, work inwards, and their effect must be, in a relaxed state of the foot, to cause a stream of water to flow into its lacunæ, and so to effect its gradual dilatation. The margin of these pores seems contractile; and in any case, neither margin of pore nor wall of canal has any rigid elements to resist compression. Hence, while the first effect of a contraction of the foot is to expel by these pores some of the fluid that distends it, both pores and canals must soon be closed by the pressure of the surrounding part. The only exit left for the excess of liquid in the foot will be through the veins into the pericardium on the one hand, and the "vena cava" on the other. The discharge into the latter can only distend the vessels in the wall of the kidney and in the gills. That which is poured into the pericardium will dilate its cavity; and thus such a dilatation, I have seen by experiment, opens widely the orifices leading into the glandular portion of the kidney. The action of the two pairs of retractor muscles, which, inserted above and laterally, converge below towards the median plane of the animal, must augment the pressure on the pericardium. The liquid contained therein will now pass through the glandular into the excretory chamber of the kidney, and so out into the supra-branchial chamber.

The external orifice of the kidney is a slit, sloping downwards and forwards: its lips form valves opening outwards, so as effectually to prevent the influx of fluid from without. The action of the protractor pedis must add to the firmness of its closure under the only circumstances in which we can imagine the animal to suck or soak water into its body. Moreover, in so highly organised an animal, we can hardly believe the ciliary current of the kidney capable of changing its direction, which, in this excretory organ, must be outwards.

The true meaning of the opening from the pericardium is, that there is thus a provision for "flushing" the channels of the kidney, and sweeping out its secretions (shown to be mostly solid by Lacaze Duthiers), and affording at the same time a ready exit for the watery fluid that distended the foot, when it is no longer needed.

Finally, this provision compares functionally with that of the ciliated funnel of the segmental organ of the annelid, the Malpighian body of the renal tube of the vertebrate.

MORPHOLOGY OF THE MAMMALIAN OSSICULA AUDITUS.[1]—By Alban Doran, F.R.C.S.

(*Abstract by* J. G. Garson, M.D.)

Mr A. H. G. Doran, F.R.C.S., in a paper read before the Linnean Society, gives a descriptive and comparative account of the very extensive and unique collection of bones of the ear of the mammalia prepared by him, and now in the Museum of the Royal College of Surgeons, England. This collection, which is the largest in the world, and which has taken an enormous amount of labour to prepare, contains the bones of the ears of nearly all the families of mammalia, and affords great facilities for the study of their comparative anatomy. As the human ear bones have had the most attention paid to them, and as they are held by some to be the standard of comparison, they are first considered, and their peculiarities are described, so that the homologies of the parts of each ossicle of the lower mammals may be more clearly understood. The drawings forming the plates accompanying the work are taken from nature, and are in all cases enlargements.

The auditory ossicles in man.

In the human *malleus* the portion of the head above the articular surface is prominent, smooth, and convex, projects more on the outer than on the inner side, and is broadest laterally. Posteriorly it bears the articular surface for the head of the incus, which has very elevated borders, and is about three times as broad as it is deep vertically. This surface lies very obliquely compared with the mallei in most mammals, so that its external extremity is much higher than its internal. It is generally regarded as if it were one single facet; but on comparing it with the same surface on the malleus of a cat, it will be seen that it should be considered as made up of two facets. A faint groove, more marked in some human mallei than in others, and not reaching either extremity, divides them, running in the very oblique long axis of the whole surface. The more internal and upper facet, or portion of the articular surface *above* the groove, represents that facet which is almost completely superior in most of the lower mammals, the more external below this groove corresponding to the lower facet in many other mammals. Both rise into a high vertical convexity about the middle of the whole surface, which is there much more contracted; their planes slope downwards towards the groove, so that a concavity is formed plainly visible when the articular surface is viewed sideways. It is found that the characters of this surface undergo conspicuous changes during the growth of some genera. Between the head and the manubrium is the short constricted neck. This is rather flattened laterally, so that it is narrower vertically than horizontally. On its external aspects is a sharp sigmoid ridge, convex forwards at first, where it is near the anterior border of the articular surface, then concave forward where its

[1] *Transactions, Linnean Society of London*, Second Series, vol. i.

anterior end looses itself on the root of the manubrium. Particular attention is called to this ridge, as it is always constant in those animals where the malleus has a distinct neck, and is very plain in the mallei of the fissiped carnivora and most ungulates, appearing as the sharply curved compact neck itself, the remainder being a thin lamella of bone joining the processus gracilis. This sigmoid portion will be observed to run away from the processus gracilis, but is lost on the base of the manubrium. This is easily accounted for, if we remember that the neck is originally developed from the incurved dorsal end of the mandibular arch, the apex of which forms the manubrium itself. On the outer aspect of the neck, close to the root of the manubrium, is the root or place of origin of the processus gracilis. After examining many mallei from the human fœtal and adult skulls, hardly ever has there been found a trace of the wide lamina of thin bone filling up the angle that process forms with the neck, as in the fissiped carnivora. Believing, however, that the sigmoid posterior part of the neck in man represents the similar curved isthmus which constitutes the whole neck in these animals, it is correct to say that the short compact part of the "neck" of human anatomists in front of that sigmoid ridge is the same ossification as the upper part of the lamina when such exists. The processus gracilis cannot be seen entire unless taken from a fœtal or very young skull, not only on account of its fragility, but because it atrophies to a mere stump before adult life. It forms with the neck an angle of 125°, and runs almost horizontally forward to the fissure. It is generally bowed regularly, and is concave forward, sometimes wavy, but in all cases the degree of curvature is slight. When well preserved, the processus gracilis at birth is longer than the manubrium. Below and internal to the processus gracilis the insertion of the tensor tympani muscle is sometimes marked by a faint elevation close to or upon the manubrium representing the processus muscularis of Hyrtl, which attains a great development in some animals. The manubrium is, in man, below the average length, much shorter than in ruminants or terrestrial carnivora, although larger than in some seals and whales. It is of a stout make, broader at the base than in the Simiidæ; it is much flattened laterally, the sides looking respectively antero-superiorly and postero-inferiorly; they are also slightly convex. The extremity is slightly recurved, more so in some specimens than in others, and spatulate and smooth towards the tympanic membrane. The edges of the manubrium are thick and blunt, and the outer edge, though of a certain breadth, and giving attachment to fibres along its entire length, is rarely separated from each side by sharply defined borders, so as to constitute a true and distinct outer surface, as seen in many lower animals, especially in the Canidæ. This edge ends below in the spatulate dilatation, above in a very distinct sharp projection, well curved outwards; this is the processus brevis; its good development is a prominent feature in the human malleus. In most mammals it is only an angle at the outer aspect of the base of the manubrium, and in many it does not exist at all.

The human malleus may be taken as a good central type of the bone in mammals. It holds an intermediate position between the

almost quite neckless type seen in the Cebidæ, in *Tupaia* and the true squirrels, and the broad laminated form of the terrestrial carnivora and the artiodactylate ungulata. It is the same, with some modification, in the higher monkeys, ichneumons, and to a certain extent in the seals. It is also imitated in some of the Insectivora, Rodentia, &c.

The Incus.—In the embryo this bone holds a prominent position as the proximal end of the hyoidean arch. It varies much more in the mammalia than is supposed. In man it is of even more central type than the malleus. The body is well developed in height and breadth, and is considerably compressed laterally. The articular surface looks upwards and forwards, and is shaped to fit that of the malleus; its more external limit is on the posterior segment of the body, which is higher and more external than the anterior, in accordance with the high position of the external extremity of the corresponding area on the malleus. Its boundary opposing the inner, which is the lower extremity of the corresponding area on the malleus, lies upon the lower and more internally placed anterior segment of the body. Into the groove between the two extremities fit the convexities of the two facets on the malleus. Around the inner margin of this articular surface is a distinct groove like that which is often so strongly developed in seals; and there is a distinct concavity on the inner surface of the body, at the bottom of which is a minute nutrient foramen, often, however, filled up, even in the incus of a newly-born child. The processus brevis of the incus in man is generally not much shorter than the processus longus, and ought more correctly to be called the posterior crus. It lies as much superior to the rest of the ossicle as posterior, and in some animals it is almost superior. It is moderately divergent from the body, broad at the base, and blunt at the point, where on the inner aspect is a minute pit or concavity, generally admitted to be the true articular surface. The processus longus is slender and slightly convex, inwards at first, then forms a gentle curve, suddenly turning inwards at the extremity, which bears a flat elliptical disc on a narrow pedicle. This is the os orbiculare better termed the Sylvian apophysis, which has been considered by Sappey and others as a separate bone, but is held by the author to be an epiphysis of the incus.

The Stapes.—This bone assumes, in man, an extreme and highly developed form, and is not of a central type like the other bones. Its head is broad and shallow, the free aspect is elliptical and a little concave to articulate with the os orbiculare. The crura are long and widely divergent, so as to leave a large aperture between them at their base. The anterior one is the more slender and the straighter; it is widely grooved towards the aperture in its upper half, but the channel narrows close to the base. The posterior crus has a curve or shoulder often very marked near the head; it is deeply channeled towards the intercrural aperture by a groove almost as deep near the base as near the head. This sulcus joins under the head that which exists on the opposite crus. Sometimes the anterior crus is more curved than usual, but seldom so much as the posterior. In such cases it is still the more slender, and the groove is less marked near the base than on the posterior crus. The base or footplate is uniform, its upper border

being a wide arch, its lower slightly concave in the middle. Its posterior extremity is well rounded off, and its anterior is usually much sharper, but this distinction is often the least marked when the crura are most alike. The base is slightly convex towards the vestibule. On the tympanic aspect it is formed into a shallow tray by the prolongation along its margin of the high edges of the channel within the crura. This condition is frequently found in animals where the bone is well developed and lightly made. A bony ridge going along the tympanic aspect of the footplate is sometimes seen, but is not constant. The aperture between the crura of the human stapes is larger, when measured vertically as well as horizontally, than in the lower animals, including even the elephant; but in the golden mole the width of the aperture at the base is proportionally greater, though the head is much nearer the footplate. The presence of a minute tubercle on the inner side of the head of the stapes does not seem to be constant in man. The occasional ossification of a part of the stapedius tendon in man is well known, and is constant in many animals.

In the *Simiidæ* the ossicula of *Troglodytes niger* are taken as a whole, the likest to those of man. *T. Gorilla* resembles man in its incus and stapes, but less in its malleus. *Simia* more resembles Homo in the head and articular surface of the malleus. Though the incus of some species of *Hylobates* exhibits a tendency to low type in the malleus, and particularly in the stapes, this genus is quite anthropoid. In these ossicles, but most markedly in the stapes, these apes are much more allies to man than the lower monkeys.

The Ossicles of the Cynomorphæ or Tailed Old-World Monkeys all depart from the apes and man, and resemble the lower monkeys and most other mammals in the straight and little divergent crura of the stapes. A processus muscularis in the malleus is almost constant. In the distinctly necked malleus, with a well-formed head, and in the incus broad between the crura, *Semnopithecus* approaches the Simiidæ, especially *Hylobates*, but the stapes is not at all anthropoid. In *Cercopithecus* the malleus is nearly as high in type, but the incus is either square-bodied or high and narrow as in lower monkeys. In *Colobus*, the head of the malleus is almost as ill-developed, and sometime more flattened than in *Macacus*, and the incus is of the same form. In *Macacus*, *Cynopithecus*, and *Cynocephalus*, the malleus has a very short and constricted neck; the manubrium, which bears a processus brevis and muscularis, forms a very wide angle with the rest of the bone; the incus and stapes exhibit constantly the tendency to low types already seen occasionally in higher Quadrumana.

The Ossicles of the Platyrrhini and the Lemuridæ are peculiar. In *Ateles*, the malleus has a short neck and a rounded prominence, corresponding to the processus brevis. The articular surface is shallow, as in all the Cebidæ. The incus has not a very high body; the crura of the stapes are longer than in monkeys. In *Mycetes* and *Pithecia* the neck of the malleus is quite suppressed, and the manubrium at its root runs in the long axis of the head. The incus has a very high narrow body. The stapes in these and the genera of the Cebidæ yet to be mentioned has not so long crura as in *Ateles*,

but it is of the same form as in the old-world monkeys. In *Cebus*, *Nyctipithecus*, and *Saimaris* the malleus much resembles that of *Mycetes*, but the head is bent on the root of the manubium. In *Cebus*, the body of the incus is not higher than in *Ateles*, but in the other genera it is almost as high as in *Mycetes* or *Pithecia*. In the Hapalidæ the malleus has a rather deeper articular surface than in the Cebidae; it is quite neckless, and the head is bent upon the manubrium. The incus is generally high in the body. In the Marmozets the crura of the stapes are often fused for some distance below the head, as in mammals of a very low grade. Among the Lemuridæ, the Nycticebidæ, Galaginidæ, and *Propithecus* much resemble the Hapalidæ and *Cebus* in the malleus, but the articular surface is deep, deeper than even in *Hapale;* the head is very short and strongly bent on the manubrium. The incus has a very high body in the Galagos, but not in the Nycticebidæ. But in *Lemur* the malleus looses the specialised form common in the other Lemuridæ and new-world monkeys. There is a constructed neck and a more or less developed processus brevis. The manubrium forms a distinct angle with the neck, instead of the head being bent on it as in the Galagos, &c. The incus is not high and narrow. There is always a bony canal between the crura of the stapes. In *Chiromys* the ossicula are large and their affinities indistinct. The malleus has a much flattened head and a trace of processus brevis; in most respects it is of the Rodent type. The incus is of rather a peculiar shape, and the stapes has curved crura.

In the *Carnivora*, the ossicles of the Fissipedia differ from those of the Pinnipedia very strongly in type as well as in consistence. The laminated form of malleus prevails through the former. The crura of the stapes are straight and moderately divergent. The ossicles of the Pinnipedia—the other division of the Carnivora—are of a very dense consistence, and are very large absolutely and proportionally, except in the family Otariidæ.

The *Rodentia* are remarkable for extreme variety in form of the auditory ossicles in different families; nearly every type of malleus may be observed among them. A peculiar kind of anchylosis between that ossicle and the incus is exclusively found in certain groups of this order, and there is likewise great variety in the form of the stapes.

In the *Ungulata* the central type of malleus is the rule; the processus muscularis is usually present, but is not often of any length; the incus is rather large and variable in form; the stapes has a broad head, and is sometimes quadrilateral. In the Hyraces the ossicles are very similar to those of the Ungulata, but the incus is peculiar, the body being extremely small, while the crura are long and divergent.

The *Ossicula of the Insectivora*, as might be expected, offer great variations in the different families of this order, and there is no constant positive character to be found in any of the three ossicula. The stapes is never columelliform. The very frequent wideness of its intercrural aperture is perhaps not so much a sign of high type as an incidental feature in relation to a bony canal passing through it, or at least on account of a large vessel, unsupported by such a canal, running between the crura.

In all the *Chiroptera*, the ossicula much resemble those of the Soricidæ and allied Insectivora, particularly the malleus. The incus has in all the Chiroptera a very short processus brevis, and very long divergent processus longus. The stapes is never columelliform, the aperture is generally wide; this is necessary for the transmission of an artery unsupported by any bony canal, but may be considered as well to indicate an approach to the Primates.

The *Ossicles of the Cetacea* differ from those of the other mammalia rather in their solidity than in any great size in proportion to the whole skeleton. In size they are exceeded by the seals and sirenia, in density by the latter, but in specialization of form by no other mammals. The general diagnostic features are—in the malleus, constant, firm, bony anchylosis to the tympanic bone through the medium of the processus gracilis, with ill-developed or completely suppressed manubrium. In the incus, the great development of the stapedial crus; in the stapes, thickness of the crura, contracting or obliterating the aperture.

The *Ossicles of the Sirenia* are distinguished from their homologues in all other orders by their dense structure and clumsy form. Another peculiarity lies in their general conformation, more than in suppression or peculiar development of any of their processes. Their modified general structures mask any homologues to the ossicula of other mammals.

The *Ossicula of the Edentata* exhibit considerable variety of type; the characters of the malleus and incus are very general, whilst the stapes assumes the Sauropsidan form in one group, and approaches it in several others. Many instances are observed in this order of the ossicula of the adults of some genera resembling those of the young of others.

In the *Marsupialia*, the ear bones are always of a low type; but no point showing a low grade of development in any ossicle of any marsupial is not occasionally met with in the higher mammals, excepting that in the latter the ear bones are never seen to retain in so high a degree the fœtal consistence.

The ossicula in the *Monotremata* are very low, and correspond to their low form of skeleton, yet are thoroughly mammalian. Their distinguishing features are the peculiar form of articulation between the malleus and incus by means of a scale-like development from the head of the former and the presence of an absolutely columelliform or unicrurate stapes; otherwise, the ossicles are not much modified from those of the lower marsupials. A definite incus has long been admitted to exist, articulating with the malleus and anchylosed with it in some animals. The method of anchylosis is different from that seen in some Rodents. The column of the stapes probably represents the two crura of the stapes of the higher mammalia, but only a part of the column of the Sauropsidan columella.

The author has taken great pains in working out an elaborate and minute account of numerous minor distinctions between the ossicula of different families and genera. The variation of form of the ear bones in the Felidæ and Canidæ, in certain genera of Bovidæ, and in different families of the Cetacea, are especially worthy of notice. The monograph will, we feel certain, prove a most valuable work of reference.

REPORT ON RECENT PHYSIOLOGICAL MEMOIRS.

By J. Graham Brown, M.D.

Heynsius: "Ueber die Uhrsachen der Töne und Geräusche im Gefässsystem." *Leiden, E. J. Brill*, 1878.

In a comprehensive memoir on the causes of the cardial and arterial sounds and murmurs, Heynsius embodies the results of original experiment along with very careful reasoning, based on it and on the previous observations of others.

He controls the observations of Nolet, Thamm, Weber, and Talma, regarding the sonorous vibrations caused by the passage of fluids through elastic tubes of uniform and of varying diameter.

In 1854 he had shown that in tubes which had a contraction at one point, it depended only on the rapidity of the flow of fluid whether a murmur occurred. The murmur so occasioned he held was produced by the vibrations of the fluid as it passed into the wider part of the tube beyond the constriction.

He confirms the statement of Weber and Thamm, that in tubes of uniform lumen a murmur may be occasioned by the flow of fluids through them, but he shows that the rapidity of the current must be much greater than in the case of tubes of varying calibre. In the former case the necessary speed averaged 190 c.m. per second, while in the latter, under favourable circumstances, a flow of 12 c.m. *per sec.* was sufficient to produce a murmur.

When the lumen of the tube beyond the constriction is increased, the rapidity of movement of the fluid must be higher in order that a murmur may arise. If the rapidity of flow remains the same, widening of the tube beyond the narrow point causes a diminution of the intensity, and finally a disappearance of the murmur. So in an aneurism a murmur may be at first audible, and afterwards disappear, owing to further dilatation of the sac.

In tubes with a constriction the murmur is heard not only beyond the narrowed point, but also on the near side of it; in the latter case, however, the flow must be somewhat more rapid.

A relaxed condition of the arterial wall has *per se* no influence on the murmur.

These results are, according to Heynsius, of importance in the first place, because they show that the peculiar vibration which the fluid vein ("veine fluide" of Savart) impresses on the surrounding fluid, bears a close and inseparable relationship to the murmur; since, when the difference of diameter of the tube is increased, the murmur vanishes, although the fluid vein itself remains unchanged. It is not, therefore, the vibrations of the latter which occasion the waves of sound.

There is no reason to believe that the rapidity of blood-flow in the carotid is more than 50 c.m. per sec. during the arterial diastole, and then it is clear that the diastolic sound in the carotid, and *a fortiori*

in smaller arteries, cannot originate there by the flow of the blood-current. It must therefore be conducted from the heart.

If we take for granted that in 0·3 seconds the left ventricle empties its contents into the aorta, then it may be said that in round numbers 600 c.c. of blood pass through the aortic orifice in one second. The circumference of the aortic orifice in the human subject averages 6·98 c.m., and the lumen 3·87 sq. c.m., and thus it may be calculated that the blood current flows through that orifice at a rate of 154 c.m. in the second.

As has been already shown experimentally, this is too low a speed to occasion a murmur in a tube of uniform calibre. But Ceradini has shown that the position which the semilunar valves of the aorta and pulmonary artery assume during the ventricular systole renders the aortic and pulmonary orifices very much narrower than the diameter of these arteries immediately above their orifices. The measurements of Ceradini, however, fail to state the case fairly, as he estimated the aortic and pulmonary lumina only after death. Heynsius lays weight on the point that the lumina ought to be measured when the arteries are distended by a fluid pressure equal to the normal blood-pressure during systole. For this purpose he made a series of observations by filling the aorta and pulmonary artery with plaster of Paris under the normal blood pressure, after destroying the semilunar valves, and then measuring the circumference of the plaster cast so obtained.

The average of several measurements gives the proportion between the lumina of the ostium aorticum and the aorta at the sinus Valsalvæ as 1 : 1·8; and between the ostium and the bulbus aortæ, immediately above the sinus Valsalvæ, as 1 : 1·43. In respect to the pulmonary artery, the proportions were as 1 : 1·5, and as 1 : 1·18. Measurements made with varying pressure brought out the result that the stretching of the arterial coats was rapid with low pressures, but, when the pressure rose high, further dilatation was comparatively slight. The stretching of the aortic orifice was, under ordinary pressure, much less than that of the bulbus aortæ.

Thus, even if we leave out of the question the position of the semilunar valves during systole, it must be admitted that at the commencement of the aorta and pulmonary artery a great increase of diameter of the tube is found. As has been shown, the rapidity of current is sufficient in these circumstances to produce a murmur in each artery. These murmurs are the systolic sounds heard respectively in the aortic and pulmonary areas. (Heynsius thus recognises four systolic heart sounds—mitral, tricuspid, aortic, and pulmonary.)

After detailing further experiments relating to the conduction of the aortic sounds into the carotid arteries, for which the original work must be consulted, Heynsius proceeds to sum up this part of his subject as follows:—

1. Without a difference in calibre no murmurs arise in the arteries in the normal condition, the rapidity of the blood-current being insufficient. Those sounds which do occur spontaneously in the arteries have an origin similar to those artificially produced by the pressure of the stethoscope. They are caused by physiological constrictions of the

vessels, as for example, the systolic sound heard over the fontanelles of children, which owes its origin to the constriction of the internal carotid in the carotid canal.

2. The abnormal spontaneous murmurs heard in arteries are also due to pathological narrowing (or dilatation) of the arteries, not to an increased rapidity of blood-flow. Thus in disease of the apex of the lung the subclavian artery becomes bound down by the altered pleura to the first rib, and thus a constriction is produced in the vessel which gives rise to the systolic (arterial diastolic) murmur heard over the artery in such cases.

3. The murmur in cases of aortic stenosis is also caused by the increase of difference between the diameter of the orifice and of the artery immediately above.

4. In anæmia and pyrexia the murmur is occasioned firstly by the decrease in rapidity of blood-current, and secondly by the alteration in the calibre of the aorta.

5. The murmur heard occasionally in the aorta in cases of mitral insufficiency may be attributed to the same cause.

(Space does not allow of our following Heynsius in the argument by which he seeks to show that what with a given speed of current is a "heart sound," becomes a "murmur" when the rate diminishes. For this, and many other interesting points, his most suggestive memoir must be referred to.)

MOENS—"Die Pulscurve." *Leiden, E. J. Brill.* 1878.

In this monograph Moens details numerous experiments made by him in the Physiological Institute of the University of Leyden, regarding the fluid waves which occur in tubes, when a current passing through them is suddenly arrested or suddenly begun.

For this purpose, he made use of a metal tube of considerable length, at one point of which was let in a small glass tube closed at the upper end with a membrane, and containing a measured quantity of air. The membrane was so connected with a cardiograph, that condensation of the contained air was expressed by elevation, and rarefication by depression of the lever of the instrument. The one end of the metal tube was connected by means of a stop-cock with a pressure-bottle, while the other extremity terminated in a reservoir. (The height of the water-level in the first vessel was considerably higher than in the second, so that the current flowed along the tube from the end at which was the stop-cock towards the other.) It was seen that both when the stop-cock was rapidly opened, and when it was suddenly closed, undulations occurred in the fluid, and these causing rarifications and condensations of the air, gave cardiographic tracings, of which Moens gives numerous examples under varying conditions. The tracing alters according as the air-space is approximated to or removed from the stop-cock. Similar opening and closing vibrations are seen when an elastic tube is substituted for the metal one, and when cardiographic tracings are obtained simultaneously from several different points in the length of the tube it is seen that the undula-

tions which occur when the stop-cock is closed progress along the tube in the direction of the current, whereas the opening undulations have the character of stationary waves—that is to say, they occur simultaneously at all points of the tube.

When the tube is branched the same closing vibrations are observed which pass from the stop-cock onwards through the entire system; but in addition to these, which are common to all branches, there occur other vibrations on closing the stop-cock which are essentially independent. In each branch they are different, and they depend on the dimensions of the branch. They have the same rapidity of vibration as the opening undulations, and like them they are stationary. They occur when the branch terminates in a reservoir, and when there is a great difference between the maximum and minimum tension. The occurrence of such waves in the arterial system will probably throw some light on the double arterial sound heard in certain cases.

KNOLL—"On Pulse Tracings." *Arch. f. exp. Path.* ix. s. 380; *Cbl.* 1879, s. 167.

The author details a great number of observations on the influence which the medium arterial pressure, and the frequency of the cardiac pulsations, and the respiratory movements exert on the sphygmographic tracing and on each separate curve. In dogs the femoral artery was employed. The animals were narcotised, and only in a few instances was it found needful to employ curara in addition. The sphygmograph used was part of the polygraph of Maurice and Mathiew. At the same time, the blood-pressure was measured by means of a mercurial manometer placed in the corresponding artery of the other leg. In the human subject the tracings were obtained with a modified Mach's sphygmograph.

In regard to the influence of the mean arterial pressure on the tracings, the author found, when sources of error were carefully avoided, that the elevations and depressions in the tracings expressed pretty closely the fluctuations of the mean arterial pressure. Gradual rise or fall of the pressure does not, of course, produce such a noticeable change in the tracings as more rapid changes. By measurement it is possible to notice a difference in the height of the tracings where the blood-pressure changes were equal to 20–30 mm. mercury. The influence of the mean pressure on each individual curve was studied partly by producing dyspnœa, partly by paralysing the vagus, and partly by intra-venous injection of nitrite of amyl. The results arrived at were very much those of Wolf and of Landois.

The influence of the frequency of the cardiac contractions on the tracings was chiefly observed in animals in which the vagi were divided and irritated. If the pulse is made very slow by electrical irritation of the vagus, the base line of the curves sank under the level at which it formerly stood. The amount of this depression depends on the height of the mean arterial pressure before the irritation was commenced. If the pressure was high, then the base line falls considerably, the percussion-stroke is very perpendicular, and the

distance between it and the secondary wave increased. But if before the irritation the mean pressure was low, then the reverse takes place.

DEMANT—"On the Action of Human Intestinal Juice." *Centralbl. f. d. Med. Wis.* 1879, s. 115 (*orig. mit.*).

The author had an opportunity of making observations on intestinal juice in a patient in whom herniotomy had left a complete fistula at the lower end of the small intestine, so that the intestinal tract was divided into two parts completely separated from one another, in the lower of which pure intestinal juice collected. With the secretion so obtained he performed a number of experiments to ascertain its power of digestion. The results of these are briefly as follows:—

1. Human intestinal juice is a thin, clear fluid, of strongly alkaline reaction.
2. The amount secreted is not large. During the act of digestion more is secreted than at other times. During the night there is almost no secretion at all. Purgatives (Carlsbad salt) exercise no influence on its quantity, composition, or power of digestion.
3. It contains no peptic (albumin digesting) ferment, and it is quite indifferent to all protein bodies.
4. It changes starch into grape-sugar.
5. Cane-sugar is also transformed into grape-sugar by the action of intestinal juice.
6. Fats which contain free fatty acids are emulsioned by intestinal juice, but neutral fats are not.

HEIDENHAIN—"On the Secretion of the Glands in the Fundus of the Stomach." *Pflüger's Archiv.* Bd. xix. s. 148.

The author has already examined the secretion from the pyloric end of the stomach, and he now proceeds to investigate that from the glands of the fundus.

The necessary operation is carefully described, and that it should be performed under antiseptic precautions insisted upon. In a previously narcotised dog a median incision is made in the abdominal wall from the ziphoid cartilage downwards, of sufficient length to allow the stomach to be drawn out. Two temporary legations are then placed round the viscus so as to cut off the pyloric and cardiac ends from the fundus. Incisions are made in the central portion, which, when completed, form a rectangular flap which is retained outside of the abdominal wall after the stomach, released from its ligatures, is allowed to fall back into the cavity. The cut edges of the wounds are sewn together, and the protruding flap is formed into a pouch which lies on the anterior wall of the abdomen, and in which the secretion of that part of the stomach collects. The operation is a very fatal one, but Heidenhain was fortunate enough to see two dogs live sufficiently long subsequently to allow of observations being made, the results of which he embodies in this memoir. The mucous membrane of the fundus supplies a secretion in which the thick tenacious mucous

of the superficial epithelium separates itself from the thin secretion of the glands proper. The secretion was always clear and never yellowish, as Bidder and Schmidt found. The proportion of solid matter averaged 0·45 per cent. The secretion gave the following reactions:—Boiling—scarcely perceptible opalescence; alcohol—slight opalescence; concentrated nitric acid—no opalescence or any yellowing when heated; chloride of platinum—after long standing, slight opacity; neutral acetic of lead—stronger opalescence; tannic acid—still more opalescence. Pure fundus secretion is more acid than the mixed gastric juice.

Conditions of Secretion.

1. Purely mechanical irritation of the mucous membrane only produces a local secretion. When the stomach was filled with an indigestible material, such as yellow elastic tissue, secretion was excited wherever the food touched the mucous membrane, but not in the pouch.

2. The act of secretion, however, spreads to other parts when absorption takes place.

Thus it is necessary to distinguish a primary and a secondary act of secretion. The former is only slight in amount, and is limited to the locality irritated by the ingesta. The secondary is of greater amount, and depends on the act of digestion.

The Composition of the Secretion during the Progress of Digestion.—The amount of pepsin diminishes rapidly with commencing digestion, and during the second hour reaches its lowest point. It then rises, and during the fourth and fifth hour its amount is greater than at first. In the later hours it falls very slightly.

The amount of pepsin in the secretion does not run parallel to the proportion of pepsin in the mucous membrane. When the former is at its maximum (fifth hour), the latter is low (Grützner). It is thus necessary to conclude that the increase of pepsin in the secretion at the fourth and fifth hour is to be explained by the fact that in spite of the small quantity of pepsin in the glands, more passes into solution, because it is in a more soluble condition.

The acidity of the fundus secretion varies very little, and stands in no relation to the quantity of pepsin it contains.

SEEGEN—"On the Changes produced in Glycogen by Saliva and Pancreas Ferment." *Pflüger's Arch.* xiv. s. 106.

Concludes—1. Glycogen is not entirely changed into sugar by the action of saliva and pancreas extract. When the fermentation is completed, from 60 to 75 per cent. is so changed.

2. The sugar so formed is not grape-sugar, as it possesses a decidedly smaller power of reduction, and a much higher specific relation. The former is only 66 per cent. of that of grape-sugar, and the latter varies from 120°-130°.

3. Diastase acts in an analogous manner to saliva and pancreas ferment.

4. Starch also is not entirely changed into sugar by the action of these ferments, and the sugar so formed likewise possesses the above-mentioned characteristics.

5. Keeping in view the manner of their production, and their correspondence as regards power of reduction and relation, the varieties of sugar formed by the action of saliva and pancreatic ferment on glycogen and starch may be called *ferment sugar*.

6. By boiling with acids (hydrochloric and sulphuric), only about 75 per cent. of the glycogen is changed into grape sugar. A complete transformation of the glycogen takes place when a solution contained in closed tubes is heated to 100° C. for 36–48 hours in a water bath.

7. The sugar formed in the liver is grape sugar.

8. The second transformation-product produced by the action of ferments is dextrin. This appears in two forms: (*a.*) *Achroodextrin* at the moment when the opalescence of the glycogen solution disappears. This achroodextrin is precipitated by weak alcohol, and by the further action of the ferments it is changed into sugar. When the fermentation is concluded, there remains behind (*b.*) a second dextrin, which dissolves with difficulty in 90 per cent. alcohol, and which cannot, by further fermentation, pass into sugar. On account of the resistance it offers to acids and to ferments it may be called *dystropodextrin*.

ABSTRACTS OF PATHOLOGICAL PAPERS: EVIDENCE FOR THE UNITY OF PHTHISIS.

I. GRANCHER, Tuberculose Pulmonaire, *Archives de Physiologie*, 1878 (pp. 38, with 3 plates).

II. GAULE, Anatomische Untersuchungen über Hodentuberculose (Phthisis testis). *Virchow's Archiv*, 1877 (pp. 62, with 1 plate).

III. DOLERIS, Recherches sur la Tuberculose du Larynx, *Archives de Physiologie*, 1877 (pp. 46, with 1 plate).

(*Abstracts by* C. CREIGHTON, M.D.)

THE paper by Dr Grancher may be selected for analysis as being one of the latest expositions, in detail, of the views on pulmonary phthisis which have been lately advocated by several pathologists, more especially in France. The opinions in question profess to be a return to the position maintained by Laennec, that miliary granulations and "tubercular infiltrations" belong to the same category. In the history of pathology that opinion was superseded by the doctrine introduced by Virchow (if not actually initiated by him), that tubercles are comparatively rare in phthisis of the lung, and that the so-called tubercular infiltations, forming the most prominent feature of the disease, are simply the caseous products of bronchitis, peribronchitis, and catarrh of the alveoli. The disease was thus brought within the familiar category of inflammations, and the exciting causes of the disease were rendered intelligible in a corresponding degree. The great advance upon the earlier doctrine, that is implied therein, has naturally been maintained; and in that respect there has been no return to the position of Laennec. It will appear that the modern French doctrine of pulmonary phthisis, is from first to last based upon the rational analysis of the disease that was first instituted with sufficient precision and detail by Virchow. In so far as that doctrine asserts the miliary tubercles and the "infiltrations" to be of the same nature, it may be said to be cast in the same form as that of Laennec; but if there be a question of reverting to some earlier view, it is not to the view of Laennec, but to that of Reinhardt (contemporary with and diverging from that of Virchow) that the most recent pathology may be said to have gone back. (*Berliner Charité-Annalen*, 1850.)

The observations of Dr Gaule on tuberculosis of the testicle (2) belong to the literature of 1877; but the opportunity may be taken of introducing this extensive research to the notice of English readers, in connection with the analogous paper on phthisis of the lung. If not in its formal conclusion, yet in the general strain of its argument, the research of Gaule must be held as corroborating in the case of phthisis of the testicle the view that Grancher holds with regard to the unity of pulmonary phthisis. There is, in fact, close parallelism between the two series of observations.

The paper on tuberculosis of the larynx (3) is in like manner instructive, as read side by side with the two former.

I. Observations of Grancher.—A few pages at the beginning of the paper are occupied with an instructive sketch of the general anatomy of the lung, following a method adopted by Charcot.

The pathological part opens with a definition. Tubercle is a *fibro-caseous* new growth of nodular form, and it is characteristic of a diathesis-malady, viz., *tuberculosis*. The lung is a favourite seat of this diathesis; and the manifestation of it in that organ gives rise to *pulmonary tuberculosis*, a disease that may develop itself in three clinically distinct forms—(1) the acute or *pneumonic* form, (2) slow or *ordinary* consumption, and (3) the sub-acute or *granulation* form. The author promises to treat of each of the three varieties separately, and to add a chapter of historical criticism. The instalment of this projected treatise that has already appeared relates to the acute variety of phthisis, designated by the author indifferently *tuberculous pneumonia*, or pneumonic tuberculosis.

By tuberculous pneumonia is understood the disease (of not infrequent occurrence) presenting the following clinical features: a previously healthy individual (with or without tuberculous family history) has a sudden attack, not distinguishable from and diagnosed as ordinary acute lobar pneumonia. But the defervescence does not follow in due course, the consolidation persists, and the expectoration becomes muco-purulent or sanious. In one or two months the patient dies. The case, says M. Grancher, is one of tuberculosis. It is as much a case of tuberculosis as if the lungs had contained the small grey translucent tubercles. The pathological process is essentially the same in both cases, and there is no such disease as caseous pneumonia in contradistinction to tuberculous pneumonia. It is in this sense that M. Grancher contends for the unity of phthisis.

The author then proceeds to describe the state of the lungs, and to trace the steps of the pathological process. In one of the lungs the upper lobe is partially transformed into a cheesy mass, while the middle and lower lobes are in a somewhat different state. They contain, on a rose-red and gelatinous background, a number of small whitish masses, round or oval. These nodules give way under the pressure of the fingers, and are found to be composed of a soft cheesy substance. Some parts of the lower lobe may be found merely congested, and still crepitant, and studded with still smaller and firmer masses. Those differences are merely the differences between the older and the more recent stages of the same process; the cheesy mass at the apex has resulted from the fusion of smaller isolated masses such as may be found at the base. It is of no advantage to study the former, as nothing distinctive can be found in them; the changes should be studied in their earlier stage, and for that purpose the lung of a patient that has died rapidly of tuberculous pneumonia, say after an illness of fifteen days, is most serviceable. The record of such a case is then given, death having been really caused by an intercurrent attack of diphtheria. The observations recorded in this selected case are such as the author has invariably found in a wide experience—a quickly fatal disease,

having the symptoms of acute lobar pneumonia, and revealing the existence of small scattered masses in the lung, which become confluent, and in the end form an extensive aggregate of caseous substance. The following account of these small scattered masses justifies, in the author's opinion, their title to be called tuberculous, equally with the smaller grey translucent masses to which the name has been restricted since the distinction was made by Virchow. Each of the scattered masses, whatever its size, corresponds to the universally-accepted description of a tubercle: it is caseous in the centre, and it has a peripheral zone of embryonic tissue. Such is the miliary tubercle; such, also, is the pneumonic tubercle. In studying the origin of the latter, the author considers—(1) the central caseous zone, (2) the peripheral zone of embryonic tissue, and (3) the zone of secondary pneumonia round the tubercle.

(1.) *Caseous zone.*—The caseous centre of each tubercle shows, on careful preparation, the section of a small bronchus and artery, and the indistinct outlines of the encircling alveoli. It is the small bronchus that forms the point of departure of the growing tubercle. Within the bronchus, throughout the thickness of its walls, and in the encircling lymph-space, there are found large numbers of cells whose accumulation fills up the tube, dissociates the layers forming its walls, infiltrates the peripheral connective-tissue, and so forms a nodule. In this new formation there are concerned indifferently:—the surface epithelium, the connective-tissue and muscle cells of the bronchial wall, the lymphatic endothelium, and the connective-tissue cells of the investing fibrous-tissue. The author then describes the cellular changes in each of the tissues enumerated. The elastic fibres alone retain something of their original characters, and they may be distinguished up to a comparatively late period in the midst of the caseous nodule. The foundation of the tubercle is laid in this extensive bronchial and peribronchial accumulation. Next, the neighbouring twig of pulmonary artery is involved, and the bronchial vessels. The whole of their tissues, endothelial and parietal, are in like manner drawn upon in the hyperplastic process; and the new formation round these independent centres is fused with the earlier peribronchial one. In the neighbouring pulmonary alveoli, the bounding walls are occupied by rows of small cells, and the cavities are filled with inflamed and desquamated epithelial cells. A detailed description is then given of the changes in the individual hyperplastic cells by which the caseous transformation is rapidly brought about. The author considers that the caseation depends primarily on a deep-seated disturbance of nutrition, enchanced, secondarily, by the mechanically retarded capillary circulation.

(2.) *Embryonic zone.*—This zone plays an important part in the production of the tubercle, but it is a less certain character than the central or caseous zone. It is constant in tubercles of the human subject, and it occurs as the periphery not only of the microscopic nodule, but also round tubercles that may be as large as a nut. In the large caseous masses which occur among the pneumonic tubercles, this limiting zone may sometimes be seen round each of the primitive

nodules, which by their fusion make up the mass. Confining the attention, however, to one of the single isolated tubercles, the embryonic zone has the following characters. It does not in every case completely surround the caseous zone, but may in some cases be massed on one side. The cells are small and rounded, with varying proportion of nucleus and cell substance; in cases where the tuberculosis is rapidly fatal, the zone is composed almost entirely of nuclear cells, but in slower cases a considerable quantity of intercellular substance is produced. The cells with embryonic characters are derived from the connective-tissue of the walls of bronchi, blood-vessel and alveoli adjoining the caseous nodule. At those new points of departure, the same pathological process which first set up the formation of a tubercle, recommences. Inasmuch as the alveoli encircling the caseous centre present a relatively greater range than the vessels or bronchi, it is the connective-tissue of their walls that contributes most to the peripheral zone. The new-formed cells occupy at first the interfascicular spaces of the connective-tissue, being ranged in linear rows, and they afterwards grow to be small heaps. The fate of the peripheral embryonic zone varies. If the tubercle runs its course rapidly, the embryonic cells become caseous, and so form part of the central zone, while a new embryonic zone is being produced under the same conditions as the first. In this way the caseous area extends. But if the growth of the tubercle be slow, if it takes weeks or months to reach the size of a lentil, the embryonic zone has time to reach the natural issue of fibrous or cicatricial tissue. The embryonic zone has the same title to be considered tuberculous as the caseous zone; and it is within it and at the cost of it that the new tubercles form by which the primitive focus of disease is extended. If the original centre of caseation is found to be enclosed by a zone of fibrous or adenoid tissue, forming a kind of barrier, that condition is not due, as has been sometimes supposed, to an *inflammatory reaction* of the tissue surrounding the caseous mass, but simply to the natural tendency of the embryonic zone (if time be given it) towards sclerosis or a fibrous condition.

Along the somewhat indefinite boundary between the caseous and embryonic zones are found the *giant-cells.* The free space by which they are often surrounded has been considered to be equivalent to a lymphatic space, the cell itself being simply a hypertrophied angioplastic cell. The marginal arrangement of the nuclei of giant-cells is equally explained on the vaso-formative hypothesis. For the rest, the giant-cells are nothing but the multinuclear cellular plates which one finds in all the acute irritative processes, and in good preparations all stages of their formation may be traced from the adjoining small cells. Such are the true giant-cells. Sometimes, however, the section of a vessel obliterated by a clot simulates the appearance of a giant-cell; that deceptive appearance may be called a pseudo-giant-cell. It occasionally happens in small tubercles that the giant-cell is in the centre, occupying the position where caseation occurs. But whenever the tubercle runs its course (*poursuit son evolution*), the giant-cells are found to occupy the region between the caseous zone and the embryonic. They indicate the degree of intensity of the process, and,

in the words of Charcot, they announce the approach of caseous degeneration.

(3.) *The pneumonic area round a tubercle.*—In a preparation containing, say, four or five tubercles, the latter appear as small islands of tissue, with wide intervals between them of pulmonary substance which may appear to be healthy. These peri-tubercular belts of lung-substance are, however, the seat of a pneumonic process, which is, in the great majority of cases, not of the exudative kind, but of the epithelial (catarrhal) kind. The inherent tuberculous character which the author asserts for the embryonic zone last described, is discovered by him also in the changes that proceed in the outlying region now under consideration. In the less affected parts of this region, the alveoli preserve their normal outlines, while their capillaries are turgid and their epithelium is swollen, granular, and sometimes detached. Coming nearer to the tubercle, it is observed that the walls or septa of the alveoli are filled with small cells, and are connected with the embryonic zone by numerous prolongations of tissue; the alveolar cavities are half-full of the detached epithelial cells, which have become spherical or polyhedric, with granular substance and large nuclei. In the immediate neighbourhood of the tubercle the alveoli are flattened by pressure, and are sometimes indistinguishable owing to the extent of cell-production in their walls. Some alveoli are almost filled up by actual granulations of embryonic tissue protruding from the wall. In short, there are found in this pneumonia of the neighbouring lung-substance the same cellular phenomena that signalised the first beginnings of the tubercle—formation of embryonic cells in the walls of the alveoli and in the perivascular connective-tissue, and accumulation of epithelial cells in the alveolar cavities.

In these outlying alveoli, a kind of giant-cell occurs, which almost fills the alveolar space, its nuclei being peripheral. It is almost certainly derived from the fusion of the epithelial cells that have been shed into the alveolus, with or without multiplication of their nuclei. Instead of being fused into giant-masses (to become caseous) the epithelial cells may undergo degeneration into vitreous, or colloid, or wax-like substance.

The perituberculous pneumonia deserves to be called tuberculous equally with the caseating nodule round which it forms. It wants nothing but the nodular form, but it reproduces the two grand characters of tubercle, a process in the interstitial tissue conjoined with a process in the surface epithelium, and it corresponds to the variety of infiltrated tubercle.

The author sums up the foregoing points under seven heads, concluding with the following more general preposition:—Caseous pneumonia does not exist, but there exists a *tuberculous* pneumonia—an inflammation of a special nature, with an ulcerative tendency, and characterised always by the presence of pneumonic *tubercles.*

II. Observations of Gaule.—The disease which has very generally been designated as tuberculosis of the testicle, presents, says Gaule, a considerable variety of anatomical features. In all the cases, however, the clinical symptoms are the same, and the diagnosis of tuberculous

testicle is readily made. Again, this disease is found in combination with the most various tuberculous changes of other organs, *e.g.*, tuberculous ulceration of larynx and of intestine, tubercles of the pia mater, and general tuberculosis of the viscera, not to mention pulmonary consumption. Thirdly, whatever may be the variety of anatomical features that correspond to the clinical notion of tuberculous testicle, the whole range of these variations is often to be seen in one and the same diseased testicle. These statements are borne out by the elaborate tabular survey of eighteen cases which Gaule has collected from the writings of various authors. The object of his investigation (suggested by an earlier and less extensive work in conjunction with Tizzoni) was to discover the connection between the various anatomical conditions that are found in tuberculous testicle. To this end he collected sixteen cases, some of them old museum specimens, others obtained at *post-mortem* examinations, and others from the operating theatre. The sixteen cases are then described one by one in greater or less detail. The survey of this series of cases brings out the same points as the table of eighteen cases collected from other authors, viz., the association of the disease with one tuberculous condition or another elsewhere in the body, and the varieties of structure within the same diseased testicle. Although it is true that the various conditions were more or less combined in each case, yet there was usually one kind of new formation distinctive of the case. Underlying all the varieties of diseased products, there was one uniform morbid process, namely, catarrh of the epithelial surface, with ulcerous invasion of the subjacent tissues, and caseous degeneration of the hyperplastic or inflammatory products. It will be afterwards mentioned that the ulcerating and caseating catarrh usually begins in the epididymis. Taking first the various forms which the morbid products ultimately assume in the testicle, there is one that has to be specially mentioned. Perhaps the most common form of tubercles in the testicle (the only kind recognised by some authors) are fibro-caseous nodules scattered throughout its substance, having the size of a pin-head up to that of a pea. In the outer zone of such a nodule are found the sections of seminal tubules, still recognisable as such; the tubules can be followed from a point at which there is no actual new formation, into the periphery of the nodule, where they may be observed to become thicker in their walls and narrower in their lumen, while their epithelium plays an equally important part in giving the nodule its distinctive characters. The central part of the nodule, already becoming caseous, is equally found to have originated as a localised thickening in the course of a bundle of tubules. The intertubular tissue has contributed a large proportion of the new growth. The nodule consists of seminal tubules with thickened walls, of tracts of fibrous tissue running concentrically round the individual tubules and round the whole nodule, and of the products of regressive metamorphosis. It is, in fact, made up of the normal constituents of the organ in an altered state; the change is of an inflammatory nature, and it affects the testicle not only where the nodular enlargements have arisen, but in a less degree throughout the whole parenchyma. It is essentially a

"perispermatophoritis," and the nodules are perispermatophoric nodules. The inflammatory process exists not only where the nodule is, but along the sides of the tubule or bundle of tubules, at each end of the apparently circumscribed nodular swelling, and thus connects one nodule with another. The process extends also into the rete testis and epididymis, and will be found, in fact, to have invaded the testicle from that side.

The sections of such nodules look like reticular tubercles. The swollen epithelial cells of the tubule have become fused into one mass by the agency of the normal cement substance between them; their nuclei having retained their original position, and the section of the tubular contents gives the figure of a giant-cell with a peripheral circlet of nuclei. The formation of new cells in the wall of each tubule, in the intertubular tissue, and in the interstitial tissue generally, supplies the other elements of the tubercle, and the concentric arrangement of the same.

Besides the fibro-caseous nodules above mentioned, the author found, in his series of cases, varieties of new formation such as the following:—(1) Cylindrical or pear-shaped fibrous masses extending into the testicle from the corpus Highmori, and following the natural subdivision of the organ into lobules; (2) a condition differing from the isolated and scattered fibro-caseous nodules as in the case first described, and differing also from the wedges of fibrous substance invading the testicle as a compact whole, and showing, in fact, the implication of whole lobules, but without the excessive implication of the intertubular tissue by which the intervals between individual tubules or bundles of tubules were effaced; (3) fibro-caseous nodules in the region of the mediastinum testis, with narrow yellowish lines radiating therefrom; (4) lines of fibro-caseous appearance radiating from the mediastinum, but unassociated with any nodular formations whatever; (5) numerous yellowish-white nodules throughout the organ, not of fibro-caseous structure, but richly cellular; (6) the whole testicle full of grey transparent granulations, of a size scarcely visible up to the size of a pin-head, and indistinguishable from disseminated miliary tuberculosis; and, lastly, a condition that in no marked particulars differs from interstitial orchitis, except that giant-cells were found in the hyperplastic tissue. (Giant-cells were found also in the condition mentioned under (4); the reader is left to suppose that the giant-cells in these cases were of the same nature as those formerly described, viz., intratubular formations.)

It has been said already that each case showed more or less of the whole range of products above enumerated; although, it is obvious, that the predominance of one or other form gave the cases their distinctive features. Catarrh of the epithelium, and ulcerating invasion or inflammation of the subjacent tissue, was the initial process in them all; even the disseminated translucent nodules did not appear, on careful analysis, to belong to another category, but to be simply the result of a more acute local process. To the other extreme of intensity belong the extensive fibrous tracts extending inwards from the mediastinum.

The relation of these various forms to one another is best made clear

by tracing the course of the disease within the organ. It begins in the epididymis as a caseous-ulcerous catarrh; that is to say, a catarrh in which the swollen and cast-off epithelium becomes caseous, and which eats into the subjacent connective-tissues. From the epididymis the catarrh extends to the rete testis, and the subjacent interstitial process into the abundant mediastinal connective-tissue. The invasion proceeds from the rete testis on the one hand and corpus Highmori on the other, along certain seminal tubes and certain tracts of interstitial tissue, or along the tubular and interstitial tissue generally. In this process of extension, sometimes certain tracts and territories are more quickly reached, and the inflammatory product assumes a nodular or isolated form in the midst of the organ. In other cases the extension of the process is more rapid or simultaneous, and the result is a uniformly-disseminated host of small and richly-cellular nodules. This mode of explanation is worked out by the author in considerable detail. The process is from first to last catarrhal in the epithelium and inflammatory in the subjacent tissues, with a tendency to caseous degeneration. The products of it are tubercle-like nodules, but the author hesitates to call them tubercles. The name of tubercle should, in his opinion, be reserved for those grey transparent nodules that spring up in the interstitial tissues of the testicle, unaccompanied (except secondarily) by catarrh of the tubules. The author admits the unique position of such formations, and their sole title to the name of tubercles, but he has failed to discover any examples of them in the material that passed through his hands. Their existence rests mainly on the evidence of Virchow of Villemin and of Demme; and the author observes casually, and without following up an obvious point of argument, that the cases of Virchow and Demme were cases in which the testicle was, along with other organs, the seat of acute general tuberculosis of the miliary kind. (p. 235). If the author had classed these cases as cases of secondary tuberculosis, the designation of primary or local tubercles might still have been available for the various combined interstitial and catarrhal products that enter into his description. But if these morbid conditions in the testicle be not called tubercular (owing to the earlier and more legitimate application of the term to purely interstitial growth), they at any rate constitute a disease with distinctive or specific characters. Ordinary inflammation does not suffice to produce them, but it requires an inflammatory process which affects both the epithelial surface and the connective-tissue substratum. Of such inflammatory processes we know only the one above described, with its tubercle-like formations and its caseous issue. As he cannot call it tuberculosis of the testicle, the author calls it phthisis of the testicle. He thus summarises the paradoxical conclusion of his research:—"We have, then, to set down the remarkable fact that, in a form of disease that is always combined with tuberculous lesions of other organs, there occurs a characteristic formation which, in its size, in its histological structure, in the manner of its occurrence (localised or disseminated), and in its destiny to become caseous, is the same as tubercle; but that, notwithstanding, this formation may not be regarded as tubercle, because it arises after another fashion and in a different situation."

A parallel is then drawn between phthisis testis and phthisis pulmonum. In both cases the initial process is a caseous-ulcerous catarrh, the peribronchitic nodules corresponding to the perispermatophoric, or those that form round a tubule or group of tubules as a centre. In both cases the nodules pass through the phase of reticular tubercles and become caseous; multiple nodules of miliary size simulate in both organs a disseminated miliary tuberculosis: in the lung they arise from a vesicular pneumonia, and in the testicle from a corresponding spermatophoritis. Again, in both organs, there occur confluence of the tubercle-like nodules and the formation of cavities. Finally, both organs are alike liable to the allied but distinct disease of miliary tuberculosis. From the latter disease, phthisis testis should be marked off by the same sharp lines with which Virchow has separated phthisis pulmonum from tuberculosis of the lung. There has been, indeed, a reaction, says Gaule, against that rigid demarcation, and efforts have been made to find a common anatomical expression for these allied processes. But they have not yet resulted, he thinks, in providing so secure a basis of explanation as do the principles introduced by Virchow into pathological anatomy; and even if we be to-day in a position to see more clearly into the relationship in question, we owe that deeper insight to the carrying out of those very principles through which we first learned to make the distinction.

III. Observations of Doléris.—The following are some of the author's conclusions, gathered from various parts of the paper without adhering to the order followed in it. Tuberculosis of the larynx is simply laryngitis in a tuberculous subject; it is associated with phthisis of the lung, but in some cases the laryngeal symptoms take precedence of the pulmonary. The disease in the larynx is often traceable to causes acting locally, of which alcoholism is the chief. The examination of a series of cases shows that four conditions, more or less distinct in their ultimate appearance, but all of them beginning in the same way, may be made out in the tuberculous larynx. There may be (1) a diffused swelling of the mucous membrane; (2) an infiltration, analogous to the former, but with a tendency to limit itself to particular centres, ending in caseation and deep ulcerations; (3) circumscribed nodules (miliary granulations), whose existence is masked, either by their very superficial position and almost immediate ulceration, or by their deep situation beneath the abnormally thickened epithelium; and (4) a condition of sclerosis, resulting from the diffused swelling of the mucosa (1). The earliest changes in the mucous membrane of the larynx, to which these various conditions may be traced back, have nothing characteristic; they are simply inflammatory changes of the interstitial tissue and of the glands, sometimes acute in their progress, but more commonly subacute and chronic. Beneath the surface (abnormally papillated) there is found, on microscopic examination, a multitude of young rounded cells, with large and brightly-staining nuclei, which dissociate the fibres of the mucosa and submucosa. This embryonic proliferation infiltrates the stroma throughout its whole extent; the cells are sometimes aggregated in circumscribed heaps, and sometimes in lines or cords. The vessels and glands in the

mucosa and submucosa share in the process. The section of a vessel shows thickening of its walls, depending on the accumulation of young cells between its concentric fibres; the more central rows are round cells, while the outermost are fibro-nuclear elements. The interior of the vessel is more or less encroached upon. As to the glands of the affected region, they show analogous changes in their walls (and along the sides of their ducts), while the cavity of the gland is filled with nuclear elements which have replaced the epithelium; the epithelium of their ducts remains intact for a considerable time. The lymphatic follicles of the mucous membrane are subject to the same proliferative changes. Side by side with these formations along the walls of the vessels, along the walls of the ducts, in and around the glands, and in the lymphatic follicles, there may be readily seen collections of embryonic cells, definitely rounded and circumscribed, which have grown up at various points in the sub-epithelial tissue. They present all the characters of miliary granulations—a centre more or less uncoloured by the staining reagent, an intermediate zone of nuclei deeply stained, and a periphery of fusiform elements. Advancing from the initial stage of proliferation above described, the process may have various issues. Absolute resolution rarely or never occurs; and the reason why that fortunate termination is not reached is to be looked for in the organism itself. There is not sufficient vital power in the economy *to produce new vessels*, to make an effort towards resorption. The words printed in italics are used by the author in the beginning of his paper, but elsewhere it is rather the obliteration of the pre-existing vessels that is made to account for the issues of the morbid process. "If the vascular obliteration be complete, there is rapid death and suppurative elimination; if it be slow and less absolute, there is caseation and slower elimination; if the obliteration be still less extensive, organisation into connective-tissue is possible." Following the degrees of vascular activity, there is a scale of anatomical product. At one extreme, the caseous masses, at the other extreme the sclerosed tissue, and between them the grey granulations. The patches of sclerosed substance in the larynx are not due to an ordinary inflammation of the tissues near the tubercles. On the contrary, they are part and parcel of the tuberculous products, differing from the caseous areas in their comparatively safe transformation into connective-tissue, and owing that safe termination to their superior vascularity. Corresponding to this sclerosis in the more extensive or continuous tracts of embryonic new formation, there is sometimes a change in the isolated miliary tubercles, which saves them, as it were, from the fate of caseous degeneration, and leaves them in the passive condition of "fibrous tubercles."

All the forms of morbid products above described have an equal right, the author thinks, to the title of tuberculous. The cellular productions scattered through the interstitial tissue, in the parenchyma of the glands, along the vessels—collected in the form of nodules or dispersed in the form of infiltrations—appertain to tuberculosis. The unvarying phenomenon which establishes their common nature is the diminution, if not the total suppression, of the blood-supply.

Notices of New Books.

THE ATLAS OF HISTOLOGY. By E. KLEIN, M.D., F.R.S., Lecturer on Histology at St Bartholomew's Hospital Medical School, and E. NOBLE SMITH, L.R.C.P., M.R.C.S., late House Surgeon to St Mary's Hospital. 4to, pts. i. and ii., 6s. Smith, Elder, & Co.

THIS is the most handsome and best work on the subject which has yet appeared in this country. It is "intended to be a pictorial representation of the structure of the tissues of man and other vertebrates; its chief aim being to teach, not so much the history of histology as histology itself in its modern aspect." The illustrations are excellent, and do great credit to the skill and accuracy of the authors, and to the artistic powers of Mr E. Noble Smith, by whom they were drawn and executed. The text is clear, without needless verbosity, and comprises, besides the explanations of the illustrations themselves, and a good deal of other matter, and, indeed, forms an excellent treatise on histology. The two parts that have been issued contain blood, epithelium and endothelium, and connective tissues. All the cells of these tissues are described and represented as consisting of a very minute network of fibres (as shown in the colourless blood-corpuscles by Heitzmann), containing a hyaline or transparent ground-substance in its meshes The movements and changes of form of the cells are attributed to contraction of these fibres. The nucleus is composed in a similar manner; so that there is an intra-nuclear as well as an intra-cellular network, and these are continuous with each other. Moreover, the cilia are represented as prolongations of the fibres of the intra-cellular network; and the following suggestion is given as their movement:—

"It is quite possible that this movement is caused by the contraction of the intra-cellular network in this way: Supposing the intra-cellular network contracts to one side in a horizontal diameter, each such contraction acts naturally on the lower end of the cilia, which thereby are pulled to the same side, while the outer or freely projecting portion of the cilia is driven in the opposite direction, each cilium representing a lever, the short arm of which is within the cell in connection with the intra-cellular network, the long arm being the freely projecting part, and the fulcrum or fixed point lying in the membrane covering the free cell border. When in the next moment the contraction of the intra-cellular network ceases the cilia move again in the opposite direction. These two phases would correspond to the to-and-fro movement of the cilia," p. 12.

The "goblet cells" are caused, or rather the goblet form is given to the columnar epithelical cells, by the secretion of mucous in them, and the resistance to its escape by the membrane covering the free surface of the cell. Ultimately this membrane becomes detached, and the mucous is poured out.

The account of the endothelium of the lymphatic system, and of the germinating cells surrounding the stomata on the peritoneum, is to a considerable extent taken from Dr Klein's *Anatomy of the Lymphatic System*.

We trust the succeeding parts will maintain the character which the first two have given to the *Atlas*.

Journal of Anatomy and Physiology.

ON SUPERNUMERARY NIPPLES AND MAMMÆ. WITH AN ACCOUNT OF SIXTY-FIVE INSTANCES OBSERVED.

By J. MITCHELL BRUCE, M.A., M.D. Lond., F.R.C.P. Lond., *Assistant Physician to Charing Cross Hospital, and to the Hospital for Consumption, Brompton; Lecturer on Materia Medica, Charing Cross Hospital Medical School.* (PLATE XXIII.)

EVERYONE is familiar with the statement contained in most works on general anatomy, that additional or supernumerary nipples may occur on various parts of the body. Most practitioners of medicine also will probably be able to recall one or more instances of this abnormality that have fallen under their observation. Physicians having daily occasion to examine physically a large number of individuals, and surgeons engaged in the examination of recruits will naturally enjoy the best opportunity of meeting with supernumerary nipples; and the number of cases thus seen at different times must have been very great. It is a remarkable fact, however, that the number of instances of additional mamma or nipple actually recorded is very small, probably not greatly exceeding 100. Perhaps this fact should not be called remarkable when the comparative rarity of the abnormality is considered, as well as the small amount of practical interest or importance which its occurrence at first sight appears to possess. The natural result of the neglect to record the occasional observation of the abnormality has been that it is regarded by most anatomists as excessively rare; and further, that since striking examples only of supernumerary mammæ have been described, as met with chiefly in pregnant

and suckling females, perfectly erroneous views prevail with respect to its general characters, varieties, and usual sites, and the relative frequency of its occurrence in the two sexes. The writer had met with several well-marked examples of supernumerary nipple previous to the commencement of the investigation to which the present paper relates. About the end of the year 1875 it happened that two or three cases of the kind came under his observation together, and it was determined to look more carefully for the abnormality in future, to keep a record of any case that might be discovered, and to ascertain, by reference to literature, how much was accurately known upon the subject. The investigation has been carried on for more than three years, under circumstances highly favourable to the observation of a large number of individuals; and the result is the collection of a considerable number and variety of instances of the abnormality.

Meanwhile, in June 1878, a very important paper upon the same subject appeared in *Virchow's Archiv* (vol. lxxiii. part 2, p. 222), by Professor Leichtenstern of Tübingen, entitled "Ueber das Vorkommen und die Bedeutung supernumerärer (accessorischer) Brüste und Brustwarzen," which gives the entire literature of the subject with such remarkable fulness that the writer of the present paper has been spared all trouble in the same direction.[1] Professor Leichtenstern has thoroughly entered into the various points, morphological and teleological, connected with supernumerary mammæ; and having analysed all recorded cases with respect to the number, situation, frequency of occurrence, subjects, &c., of the abnormality, has stated his conclusions definitely and succinctly. We shall frequently have occasion to refer to these conclusions, and to show wherein our own results agree with them and wherein they differ from them.

In the present paper the writer proposes to confine his remarks as far as possible to a statement of the facts that he has observed respecting supernumerary mamma, and to avoid all speculation upon the significance of the abnormality. *Firstly*, An account

[1] Many of the cases collected in Leichtenstern's paper were derived from English sources. It is not considered necessary to burthen the present paper with references which can easily be obtained elsewhere; but the papers of Dr Handyside and Mr Cameron in vols. vii. and xiii. of this *Journal* may be specially named.

will be given of the absolute number of instances that were found, along with a table setting forth the chief features connected with each. *Secondly*, An analysis will be made of this collection, with the result as regards the number, situation, subjects, &c., of the abnormality. *Thirdly*, A special series of observations will be described, which was made to determine accurately the frequency of occurrence of supernumerary nipples amongst all persons taken indiscriminately, and the result. *Fourthly*, A calculation will be made from the preceding series of the relative frequency of supernumerary nipple in men and women. *Fifthly*, Some account will be given of the appearance of supernumerary mammæ or nipples, and of the varieties of them that are met with. *Sixthly*, The subject of the functional activity of these supernumerary organs will be noticed. *Seventhly*, The question of inheritance of the abnormality will be briefly discussed. *Eighthly*, The conditions found associated with supernumerary nipples will be referred to; and, *lastly*, The occurrence of the abnormality in extraordinary situations.

I. Absolute Number of Cases found.

The subjects of the present investigation were out-patients attending at the Hospital for Consumption, Brompton, under the care of the writer. From the 13th of December 1875 till the 18th of January 1879 every case of supernumerary nipple that was discovered during physical examination of the patients' chests was recorded and briefly described. It must be noted that, while it is probable that few cases escaped observation during this period, especially towards the end, when the peculiarity was a subject of special interest, and the appearance had become familiar to the eye, a regular and systematic search was not made for the abnormality. During the time included between the dates just given 3956 persons were examined with respect to the physical condition of their chests, and a small proportion of this number on more than one occasion. In male patients, without exception, the whole trunk, as low as the umbilicus, was displayed, and the examination was commenced with a careful determination of the visible signs. Very few instances of supernumerary nipple would have

escaped observation under such circumstances, if the abnormality were well marked; but the same cannot be affirmed with confidence regarding the instances to which reference will presently be made, where the various parts of the supernumerary breasts are one and all badly marked. In female patients, of whom a large proportion were free from symptoms of chest-disease, the trunk was not, as a rule, so extensively exposed to view. While the upper part of the chest was examined in every individual, the region extending from the mammæ to the umbilicus was not always visible, and any instance of supernumerary mamma that may have occurred in that situation must have remained unobserved and unrecorded. At the same time, the majority of the female patients had the front of the trunk thoroughly inspected from the neck to the epigastrium; and it must be added, that after a time a special search was generally made for the abnormality in the usual site of its occurrence, namely, the region below and within the ordinary mamma. The substance of the preceding remarks is briefly this, that the number of instances of supernumerary nipples to be presently stated as *observed* amongst a great many persons, taken not quite indiscriminately, may be safely regarded as representing decidedly less than the number that actually *existed* amongst them; and that, while the number of instances is somewhat understated in men, it is still more understated in women.

We come now to the number of cases actually observed. During a period of two years and nine months, 61 cases of supernumerary mamma or nipple were found amongst 3956 persons. Therefore, of a large number of individuals of both sexes taken not altogether indiscriminately, 1·54 per cent. presented one or more supernumerary mammæ or nipples. The following table gives the number, situation (right or left), distance from the ordinary nipple, stature, and sex of each case observed, together with the "disease" from which each person was suffering:—

No.	Number of Sup. Nip.	Side of Body.	Distance from Normal.	Sex.	Stature. Ft.	Stature. In.	Disease.	Remarks.
1.	1	Left	3 in.	F.	...		Mitral Disease	Large and well marked. See fig. 3.
2.	1	Left	3 in.	F.	...		Cardiac functional	Very small.
3.	1	Left	$3\frac{1}{4}$ in.	M.	...		Mitral disease	Papilla very distinct.
4.	1	Left	4 in.	F.	...		Dysmenorrhœa	Small, very little if any pigmentation.
5.	1	Left	4 in.	F.	...		Rheum. Dysmen.	Doubtful.
6.	1	Left	$2\frac{3}{8}$ in.	M.	...		Pulmonary debility	Areola obscure.
7.	1	Left	4 in.	M.	...		Myalgia	
8.	2	Left Right	$1\frac{3}{4}$ in. $2\frac{1}{8}$ in.	M.	...		Anæmia	In a child of 7. At the age of 9 the distance had increased to $2\frac{5}{16}$ in. and $3\frac{1}{2}$ in. respectively. See fig. 1.
9.	1	Left	$1\frac{1}{2}$ in. from lower margin of mamma	F.	...		Bronchial catarrh	Very small.
10.	1	Left	$3\frac{1}{2}$ in.	M.	6	2	Phthisis	Very small. No areola.
11.	1	Left	$3\frac{1}{2}$ in.	M.	5	4	Cough	Very small; prominent papilla; slight depression without colour.
12.	1	Right	3 in.	M.	5	6	Phthisis	
13.	1	Left	No record.	F.			Sexual involution	
14.	1	Right	$3\frac{1}{2}$ in.	M.	...		Bronchial catarrh	Distinct.
15.	1 (?) 1	Left Right	1 in. 3 in.	M.	5	5	Phthisis	The right exquisitely developed. The doubtful left nipple is a distinct papilla. Chest covered with moles.
16.	1	Left	3 in.	M.	5	$6\frac{1}{2}$	Phthisis & mitral dis.	
17.	1	Left	$3\frac{1}{2}$ in.	M.	5	6	Do. do.	Small.
18.	1	Right	4 in. fully	M.	5	$2\frac{1}{2}$	Alcoholism	Fairly marked.
19.	1	Right	3 in.	M.	5	$9\frac{1}{2}$	Bronchial catarrh	Marked.
20.	1	Left	$1\frac{1}{8}$ in.	M.	...		Phthisis	Small, but well marked.
21.	1	Right	$1\frac{3}{4}$ in.	M.	...		Bronchial catarrh	A very distinct depression, with appearance of areola, with hairs growing from surface.
22.	1	Left	2 in.	M.	5	5	Phthisis	Small, but distinct.

58.	1	Left	? in.	F.	...		Uterine disorder	See fig. 4.
59.	1	Left	$2\frac{1}{2}$ in.	F.	...		Anæmia	Exquisitely marked. Papilla of second form described in text, with marginal hairs. See fig. 6.
60.	1	Left	$2\frac{1}{2}$ in.	M.	5	$6\frac{1}{2}$	Bronchitis	See fig. 7. For description see page 441.
61	1	Left	In usual situation	F.	...		Bronchitis and cardiac irreg.	Small papilla of second form described in text.
62.	1	Left	2 in. nearly	M.	...		Chronic cough	Æt 11 years.
63.	1	Right	$4\frac{1}{2}$ in.	M.	5	7	Asthma	Small.
64.	1	Left	About 3 in.	M.	..		Phthisis	Distinct papilla, apparently bi- or tri-lobed, with indefinite depression.
65.	1	Right	$\frac{1}{2}$ in. fully	M.	...		Rickets	In a child of 2 years. Very small but distinct depression of areola is marked. Not in mother.

NOTE.—The 4 last cases were observed in addition to the 61 referred to in the text.

II. Analysis of the preceding Cases.

1. *Sex.*—Of the 61 cases actually found, 47 (77 per cent.) were males, and 14 (23 per cent.) were females; that is, supernumerary nipples were observed more frequently in men than in women by 54 per cent. This result is of course of no scientific value. More important is the question of the frequency of occurrence of supernumerary mamma to every 100 of the men and women that came under observation. Of the 3956 individuals examined 1645 were males, and of these 47 (2·857 per cent.) presented supernumerary nipples. Of the 3956 individuals 2311 were females, and of these 14 (·605 per cent.) presented supernumerary mammæ or nipples. Comparing these results, we find that amongst a large number of individuals, taken not altogether indiscriminately, supernumerary nipple was found to occur more than four times as frequently in men as in women.

2. *Number of Supernumerary Nipples in each case.*—Of the 61 cases 51 were simple cases, presenting, that is, a single supernumerary nipple or mamma, and 10 were multiple, presenting more than one supernumerary nipple.

3. *Situation.*—All the instances of supernumerary nipple that came under observation were situated on the front of the trunk, below the level of the ordinary mammæ, and somewhat nearer the middle line. Reference will be made at the end of the paper to cases found by other observers in extraordinary situations.

Thirty of the single cases were situated on the left side of the chest, and twenty-one on the right.

Of the nine multiple cases, seven were cases of a right and left pair of nipples; one was a case of double left; and one was a case of a single supernumerary nipple below the ordinary left nipple, along with a doubtful right and left pair of supernumerary nipples on the anterior axillary folds.

It will be observed that all the unquestionable examples of supernumerary nipples observed by the writer were situated upon the front of the trunk, a short distance below and within the ordinary nipple. Leichtenstern's conclusion from an analysis of ninety-two recorded cases and thirteen cases observed by himself is, that "accessory nipples and breasts occur in 91 per

cent. of the cases on the front of the thorax," and in 94 per cent. of these below the normal. Of the fifteen cases seen by Leichtenstern himself, in fourteen the accessory nipple was situated below and within the nipple; and in the 15th case one was in this situation, while a second was in the axilla.

With respect to the relative frequency of supernumerary nipples on the two sides of the body, the remarkable preponderance of cases on the left side, shown by the above figures, is in accord with the results of previous observers. Of the 11 cases of single supernumerary mammæ seen by Leichtenstern, 9 were on the left side and 2 on the right; and altogether, of 52 cases on record, 36 were on the left and 16 on the right side. In discussing the cause of this curious disproportion, this author reminds us that the left mamma is, on an average, more developed, larger, and heavier than the right, and quotes the explanation of the fact suggested by Hyrtl, that mothers use the left mamma more than the right in suckling. The same relation is, however, said by Leichtenstern to hold even in the child and virgin, which, if a fact, is probably an instance of variety, "as the inherited effect of use,"[1] and a point of extreme importance in the question of the significance or origin of supernumerary mammæ. It is another interesting fact, as noticed by Leichtenstern, that in cases of unilateral amazia, or micromazia, the anomaly has been observed more frequently upon the right than upon the left side.

4. *Distance from ordinary Nipple.*—The measurements of the distance of the supernumerary nipples from the centre of the ordinary nipple, given in the table, refer, as has been said, in every case, to examples of the abnormality situated on the front of the trunk, *below and within* the ordinary nipple. A few cases of a doubtful character, observed upon the pectoral border above and without the ordinary nipple, are excluded from the table, and will be considered separately afterwards.

The measurements actually found may be classified as follows:—

a. 1 inch, in 1 case (a man of 6 feet).

b. 1½ inches in 3 cases; and 1¼ inch in a boy of 6 years.

[1] Darwin, *Origin of Species*, 1875, page 8.

c. 2 to $2\frac{1}{4}$ inches in 3 cases, and nearly 2 inches in two boys of 7 and 11 years respectively.

d. 3 inches in 17 cases, nearly 3 inches in 6 cases (including boys); and $3\frac{1}{4}$ inches in 4 cases.

e. $3\frac{1}{2}$ inches in 3 cases, and 4 inches in 8 cases.

f. $4\frac{1}{2}$ inches in 1 case; rather less than $4\frac{1}{2}$ inches in 3 cases; and $4\frac{3}{4}$ inches in 1 case.

g. 6 inches in 2 cases; and $6\frac{1}{2}$ inches in 1 case.

With respect to such measurements, the reader must observe that there are several difficulties in the way of making them perfectly accurate and trustworthy. First, in the female, the measurement has to be made upon the surface of the mamma, and is on this account probably to be frequently rejected. Secondly, it is extremely difficult to determine with any amount of satisfaction the exact distance between two points on the surface of the trunk placed vertically to each other. According as the person stoops or stands erect, a difference of as much as $\frac{1}{2}$ an inch may occur in a measurement of 3 inches. For these reasons a definite conclusion should not be arrived at with respect to the distance between the normal nipple and supernumerary nipples, or between two supernumerary nipples on the same side. The writer therefore has not hesitated to class together above such measurements as "2 inches" and "$2\frac{1}{4}$ inches;" "3 inches," "nearly 3 inches," and "$3\frac{1}{4}$ inches;" &c. When the measurements are so arranged, there is found to be some grounds for deducing what might be called the "unit of distance" between the nipples of either side. If such a fixed and regular distance may be supposed to exist according to the original type, and to hold good equally between every pair of nipples, considerable evidence is afforded by the above classification of the measurements in favour of the view that the "unit of distance" is to be regarded as three-quarters-of-an-inch.

The writer is, however, by no means certain that we should expect to find regularity of position of the nipples; or equality of distance between different couples of nipples on the same side. In the dog, which is the only polymastoid animal readily available, the position of the nipples seems to be irregular and unsymetrical; and the distance between any two nipples on the same side seems to be less behind than it is in front.

The writer certainly ascertained from repeated examinations that the distance between normal and supernumerary nipples in children may increase considerably with age.

In his account of the ordinary situation of the abnormality, Professor Leichtenstern does not attempt to define it, but confines himself to the general statement that, where it is below and within the ordinary mamma, "the distance is variable (*wechselnd*) between the normal mammillæ and the inferior border of the thorax (*Rippenbogenrand*)" (*loc. cit.* p. 227).

5. *Situation in Multiple Cases.*—Where more than one supernumerary nipple occurred, their situations were as follows:—L. 1¾ and R. 2⅞ (in a boy of seven): L. 1½ and R. 1½ : L. 4½, and R. 6 : L. 4¾, and R. 2 : L. 2, and R. 2 : L. 4, and R. 4 (in a boy of ten): L. 1, and R. 3 : L. 3¼, and L. 6½. In another case L. 4 was associated with a pair of doubtful nipples on the anterior axillary border three inches from the normal.

III. Special Investigation respecting Frequency.

Neither the frequency of occurrence of supernumerary nipples nor the relative frequency of the abnormality in the two sexes could be accurately determined by a method of observation which was neither systematic nor indiscriminate. It was therefore determined to examine with care a certain number of individuals taken indiscriminately,—that is to say, every individual that might come under observation on particular days during a certain period of time; and to record the result of the observation in every case, whether it were positive or negative. This investigation was commenced on the 31st of August 1876, and completed on the 19th of February 1877, and occupied a period of 24½ weeks, during which time 49 sets of examinations were made. The total number of persons thus examined was 315, and the result was as follows:—287 individuals presented no supernumerary nipples or mammæ; 24 individuals presented one or more supernumerary nipples or mammæ; and 4 individuals presented appearances which were regarded as doubtful instances of the abnormality. This result may be represented in percentages as follows:—91·1 per cent. presented no supernumerary mamma or nipple; 7·619 per cent. presented one or more supernumerary mammæ or nipples; and 1·270 per cent. possessed what was

doubtfully regarded as the abnormality. It may be objected that the number of persons systematically examined during the observation (315) was not sufficiently large to warrant a definite conclusion with respect to the frequency of occurrence of supernumerary mamma or nipple in the human subject generally. This objection is valid, and the reader will observe that the conclusion just reached is widely different from the result obtained from the observation of 3956 individuals described above. Amongst the latter, however, it is highly probable that a very considerable number of cases of the abnormality remained undiscovered, and that the positive results were underestimated to a corresponding extent. It must also be confessed that in the special investigation the observations were sometimes interrupted, and thus positive results only may have been recorded, which would raise the percentage. Taking the investigation for what it is worth (and as far as the writer knows, it is the only accurate investigation of the kind available), we obtain a result which must certainly be regarded as unexpected or even startling. While supernumerary nipples or mammæ have been generally described as exceedingly rare, and not more than 105 instances appear to be recorded in all literature (Leichtenstern, *op. cit.*), the result of the present investigation seems to afford sufficient grounds for concluding that the abnormality may possibly occur in more than seven out of a hundred consecutive individuals. It will be observed that this estimate is vastly higher than that given by Leichtenstern in his paper (p. 224), which is "one in five hundred persons at least." It does not appear, however, that Professor Leichtenstern carried out any special investigation to ascertain exactly the frequency of the occurrence of supernumerary nipples amongst the persons coming under his observation ; and his estimate is probably a very rough one.

Although, according to the present result, the abnormality is more than thirty-five times as frequent as this author has suggested, it must not be forgotten that to him is due the merit of having been the first to draw attention to the comparative frequency of supernumerary nipple or mamma, which, up to the date of the appearance of his paper, were probably regarded as extremely rare.

IV. Relative Frequency in the two Sexes.

The relation of the frequency of occurrence of supernumerary nipples or mammæ, as accurately determined, to the sex of the individual, has to be regarded in two aspects: first, the relative frequency of the abnormality as actually observed in the two sexes; and, secondly, the frequency of its occurrence in either sex as estimated from the results, positive and negative, of the observation of a large number of individuals. First, with respect to the relative frequency of supernumerary nipples as actually found—of the 24 cases amongst the 315 consecutive individuals, 19 were in males and 5 in females, or 79·167 and 20·833 per cent. respectively. This method of calculating the relative frequency in the sexes, though it would appear to be the only one practicable in estimating recorded cases, is not by any means accurate. The following may be regarded as correct:—of the 315 individuals specially examined for supernumerary nipples, 207 were males; and of these 19 presented the abnormality, or 9·11 per cent. Of the 104 females examined, 5 presented supernumerary mammæ or nipples, or 4·807 per cent. It appears from this that amongst more than 300 consecutive individuals, supernumerary nipples occurred very nearly twice as frequently among men as among women. It is very interesting to note that this result, which may at first sight appear remarkable, closely agrees with Professor Leichtenstern's result, and is like his opposed to the conclusion that might be drawn from cases otherwise recorded. Thus of Leichtenstern's 13 cases, 9 were in men and 4 in women; while of the 92 cases which he has laboriously collected from scattered records, and which constitute probably all the cases of the abnormality otherwise described, no fewer than 70 are in the female, and only 22 in the male. Leichtenstern satisfactorily accounts for this discrepancy by pointing out that, with quite a few exceptions, the 74 female cases occurred in pregnant or parturient (suckling) women, the abnormality being then more highly developed, the mammary region being specially examined, and the occasional flow of milk from an unexpected part attracting attention to it. On the other hand, it must be observed that the conclusion drawn with reference to sex from the present observations, and probably Leichtenstern's conclusion on the same subject, are not free from fallacy in the opposite direction. Just as the occur-

rence of supernumerary mammæ and nipples has been hitherto most frequently accidentally noticed in women for the reasons given above; so when a special search is made for the abnormality, it will be least frequently missed in men, in whom the examination is necessarily more extensively, deliberately, and accurately made than in women. This consideration, however, cannot by any means account for the great disparity between the results obtained from the two sexes; and it may be safely maintained that, according to the present observations at least, supernumerary nipples occur much more frequently in the male than in the female.

V. Varieties of Supernumerary Mammæ and Nipples.

The characters of a supernumerary nipple may vary exceedingly in different instances. Some examples might be chosen for description which in every particular except size resemble an ordinary male mammilla, while others require considerable experience for their discovery and identification. The best-marked cases present the central papilla or nipple proper, a pigmented areola, follicles, hairs, and a distinct depression on the apex of the papilla. Such a supernumerary nipple is represented in figure 7, which is an accurate delineation of the left mammillary region of a man of 73 years, 5 feet 8½ inches in height, who had been actively engaged as a soldier for many years. Examples of such a fully-developed supernumerary mammilla are certainly very rare; and the more usual condition is that one or more of the several parts of the fully-developed mammilla just enumerated may be either ill-marked or wanting, namely, the papilla, the terminal depression or opening, the areola, the follicles, and the marginal hairs. It will greatly simplify description if we discuss the chief varieties of supernumerary nipples that may be found from this point of view.

1. *Papilla.*—The presence of a papilla or prominent elevation of the skin upon the front of the chest is the feature that usually attracts the attention of the observer to the supernumerary nipple. Of the various elements of the perfect mammilla, the papilla is the element that is least frequently imperfect, badly-marked, or altogether absent. On the other hand, and perhaps on account of the very constancy of its occur-

ance, the papilla presents the greatest variety of appearance in different cases. In size and prominence it may almost rival the papilla of the ordinary male mammilla, and in one of the cases it is recorded as being "as big (say) as the end of the little finger of an infant." Between this perfect condition and complete absence, the papilla may present every variety of size. With respect to its shape and general appearance, two well-marked varieties of papilla have been observed. The first of these has just been referred to, namely, a papilla or wart-like body closely resembling the papilla of the ordinary male or female mamma. The second variety is very different, being a low ovoidal prominence, with its long diameter in the transverse direction slightly inclined downwards and outwards, and having its summit usually distinctly cleft into two lobes by an opening or deep groove parallel with the said diameter. The second variety somewhat resembles in appearance the "retracted nipple" of some female breasts; and perhaps, when it is very flat, the openings of the mammary ducts, as they are described, in the monotremes. An illustration of this variety of papilla is given in figure 5. Professor Leichtenstern probably refers to the same condition when he remarks that it "often seems as if the accessary mammæ had not advanced as far as the formation of milk-ducts. Then the embryonal skin-furrow does not rise into a complete papilla; the latter preserves rather its embryonal form, and appears in adults as a quite low prominence, superficially flattened, with a linear cleft in the middle like the os uteri."

The papilla of the supernumerary mammilla may frequently be found to be erectile like the ordinary nipple. This feature may sometimes be present even when the papilla is extremely minute, and serve to confirm its identity.

As has just been remarked, cases may be found which appear to be examples of supernumerary mammilla *without* papilla. These will be more fully described immediately.

2. The *opening* or *depression* upon the summit of the papilla is usually sufficiently distinct when the papilla is at all well-marked; and it generally catches the eye as a minute dark dot or line. In some cases a small collection of greyish-brown material in the same situation indicates the probable presence of a slight secretion. The second or ovoidal variety of papilla

just described possesses a distinct transversely-elongated opening or mouth, the lips of which are formed by the two lobes of the papilla, as in figure 5.

In a considerable number of the less-marked examples of supernumerary nipple, no opening is to be seen; and in a few cases a simple apical depression is visible.

3. *Areola.*—The areola of a supernumerary nipple may be found of any dimensions from a well-formed area somewhat smaller only than the areola of the ordinary mammilla, to the smallest possible line of pigmentation around the base of the papilla. In other cases it is entirely absent. No certain relation exists between the size of the areola and the size of the papilla; perhaps as frequently as otherwise they vary inversely with each other in prominence. The outline of the areola frequently lacks the regularity of that of the ordinary mammilla; and, instead of approaching the form of a circle, it is often rather oval transversely, with a slight inclination of the long axis downwards and outwards.

The colour of the areola varies much like its other elements. It is frequently pigmented; in other cases it is of a delicate pink tint; and sometimes it cannot be distinguished from the colour of the skin around. In the last case the areola can be recognised only by the presence of a depression similar to the depressed condition of the ordinary mammilla in some young male subjects, in the centre of which stands the papilla. Other cases were found in which in the usual situation of the supernumerary nipple, below and within the ordinary, a simple depression, transversely oval and slightly discoloured, or a simple pigment-spot, appeared to represent the abnormality. These cases are not included in the above list; but the writer has very little hesitation in calling them instances of supernumerary mamma, of which certain parts of the areola were the only elements present.

4. *Follicles.*—The follicles that are found upon the surface of the areola of the ordinary mamma, and especially along its border, are very rarely distinct, as such, in the supernumerary nipple. However, as will be described under the next head. the follicles may possibly be represented by certain other appearances in connection with the abnormality.

5. *Hairs.*—The remarks that have just been made with respect to the frequency of occurrence of follicles, apply equally to the occurrence of hairs. While they may be met with in some cases growing strong and black from the margin of the areola (as in figure 7), they are in the great majority of cases entirely absent.

A very interesting point respecting the presence of hairs in connection with supernumerary nipples appear to have a certain bearing upon the question of the significance of the abnormality. That point is the following:—A certain number of cases may be found in which one or more pale silky hairs spring apparently from the border, or even from the summit of the papilla proper. The first of this class of cases that came under the notice of the writer, while they were recorded, were regarded as examples of false supernumerary nipple; that is, as examples of a condition simulating the abnormality, but in reality only a species of mole or of hypertrophied hair and hair-follicle. But very shortly examples of supernumerary nipple were met with, so well marked in every particular that their nature could not be questioned, and yet presenting one or more hairs in the situation named. Thus in case 1—as will be seen from figure 3—the abnormality is exquisitely marked in every detail, and the papilla is large as well; while the true nature of the appearance is further confirmed by the fact that a slight "discharge" had been observed to come from it. Yet this spot presented "a rather prominent pale hair, quite close to, or even on, the papilla." The case, however, which appears to remove all doubt upon the point of the probability of meeting with a hair springing from a true supernumerary papilla is that numbered 60, and represented in figure 7. This case has been already referred to as an example of supernumerary nipple of the most unquestionable kind; and yet it will be observed that a strong hair grows from the summit of the papilla. The following note was made at the time of this case:—"2½ inches below and within the left nipple of a man, 5 ft. 8½ inches in height, is an exquisite, large, deeply-pigmented areola, a prominent nipple, and a beautiful circle of long marginal hairs, which resemble, but are distinct from, the hairs around the mammilla above. The summit of the papilla is just visibly double; and from one of the apices there grows a long

black hair exactly like the marginal ones. No other hair springs from the papilla or from the areola." It will be observed that the papilla is described as indistinctly bicapitate; and the second head may possibly represent a hair-follicle which has in some way been developed in close association with the true papilla. This explanation, even if correct, serves only to support the idea that is naturally suggested by the presence of hairs upon the supernumerary mamma; namely, that in those parts of the skin where supernumerary mammæ are found, there has evidently existed during development a twofold formative tendency, the one in the direction of the supernumerary mamma, and the other in the direction of ordinary cutaneous tissue, with hairs, sebaceous follicles, and the remaining structures. In the great majority of cases cutaneous tissue is developed, and no trace of supernumerary mamma is seen. In rare cases the very reverse is the case, and an exquisite supernumerary mamma is produced. And between these two extremes there may be all degrees of mixed development, represented by the great variety of examples of supernumerary nipples such as we have attempted to describe. The following three cases are given as illustrative of the same point. No. 59, female, presents "an exquisite supernumerary nipple, 2½ inches below and within the left nipple. A trace of a mammary gland. It is a gentle elevation, transversely ovoidal, slightly more pink in colour than the surrounding skin, with a transverse slit on the summit, nearly parallel with its long axis. A very slight margin of the same pinkish hue somewhat depressed may be said to represent an areola. True hairs, fine and light-coloured, grow from the very margin of the slit in the papilla." (See fig. 5.) No. 57, a man of 59, presents "a doubtful supernumerary nipple, 3½ inches below and within the left nipple. In that situation there is a single long black hair, close to the left border of which is an area rather larger than the head of a pin, of a yellowish-red colour, but not perceptibly depressed or smooth." In another case, not included in the list, but represented in fig. 6, the condition is as far as possible removed from the characters of supernumerary mamma, and approaches as nearly as possible the character of a portion of ordinary skin. The description runs as follows:—"3 inches below and within the right nipple is a prominence resembling an enlarged sebaceous follicle and hair-

follicle with a long hair growing from it. It closely resembles one of the follicles around the normal areola above. There is no appearance of a depression." The resemblance just noticed very naturally suggests that this peculiar prominence represents, if not a rudimentary supernumerary nipple, very probably a supernumerary marginal follicle.

When the preceding account of the various elements of the supernumerary nipple—the papilla, areola, follicles, and hairs—is reviewed, it will be observed that in a very considerable number of cases the abnormality is imperfect, either the papilla, or the areola, or the hairs and their follicles, being alone present of them, or various combinations of these; or perhaps the same in association with certain elements of the ordinary skin.

VI. Activity of Supernumerary Mammæ.

In a considerable number of the cases of supernumerary mamma on record, as has been already mentioned more than once, the discovery of the mamma was due to the fact of its functional activity—its enlargement during pregnancy and the secretion of milk by it. Amongst the fifteen cases of one or more supernumerary mammæ or nipples found in women by the writer, in none was there any secretion of milk. In one instance, however (No. 58, fig. 4), a well-formed mamma was present, as well as a nipple and areola; and reference to the accompanying plate will show how nearly the condition in other cases approached to the same (figs. 5, 2, and 3). Yet in not a single instance would the subject of the abnormality confess to any alteration of the parts in pregnancy, or during menstruation. In one case, however (No. 44), a particle of dried secretion, resembling that frequently seen upon the ordinary female nipple, was found at the mouth of the small transverse slit that represented the opening of the supernumerary nipple. In another case, the subject of the abnormality, a woman of 26, married, but sterile, stated that she had observed a slight "discharge" from the supernumerary nipple, while the ordinary mamma never yielded any discharge.

VII. Inheritance of the Abnormality.

With respect to the hereditary transmission of supernumerary nipple or mamma, the present investigation has furnished no

information worth recording. The question was put to many of the subjects of the abnormality, whether their relations had a similar peculiarity; but in no case was the reply satisfactory. In two cases only was the result sufficiently distinct to be considered worthy of record. In case 53 the mother's body was examined for supernumerary mamma, but with a negative result. In case 50 the note states that "an only sister, suckling now, has no supernumerary nipple. Mother dead." This leads to the remark that in very few instances indeed were the subjects of supernumerary nipple aware that they possessed such an abnormality. A few of them were able to say "that the spot had always been there," but the very opposite was generally the case; and mothers affirmed that "the spot was not on the child's body" sometime before. It will be seen from this of how little value the statements of persons have to be considered with respect to the occurrence of supernumerary nipples amongst their relatives.

This statement is but a repetition of the observation already made, that the great majority of the cases of supernumerary nipple recorded before Leichtenstern's paper were found in women; and that attention was attracted to them by the changes that they underwent in pregnancy and during lactation. A multitude of other cases in males and in young subjects must have entirely escaped observation. In the matter of supernumerary fingers or toes, which cannot escape the observation of the most obtuse, the statements of unskilled persons may be safely accepted respecting the inheritance of the malformation. It is altogether different with supernumerary mammæ and nipples; and nothing less than a laborious examination of the relatives of each case in which supernumerary nipples occurs can be expected to settle the question definitely. Leichtenstern found no instance of heredity amongst his own cases, but inheritance was indicated in 7 of the 92 cases recorded in literature.

VIII. Associated Conditions.

A complete list of the "diseases" for which the various persons presenting supernumerary nipples were under treatment is given in the tabulated list above; no attempt has been made to draw any conclusion from the facts there furnished. The great

majority of the patients, attending as they were at a hospital for diseases of the chest, were suffering from diseases of the respiratory and circulatory systems.

IX. Supernumerary Mammæ in other Situations.

All the preceding remarks apply only to supernumerary mammillæ situated upon the front of the trunk below and slightly within the ordinary breasts. No unequivocal case of the abnormality was found by the writer in any other situation, although notes were taken of several peculiar bodies, closely resembling mammary papillæ, upon the pectoral border between the ordinary mammilla and the axilla. Other observers have been more fortunate. Thus Dr Fitzgibbon has described[1] a case of double and symmetrical supernumerary nipples below and within the normal, associated with "two pigmentary deposits, one on either breast higher up," *i.e.*, above the ordinary mammillæ. Altogether only four cases of the abnormality have been recorded in this situation,—a fact which proves that it must be exceedingly rare. It is highly interesting to note that in all those cases the supernumerary organ was placed *outwards* as well as upwards from the normal. Accessory mammæ have, however, been found in a position still higher and more external than the preceding, namely, in the axilla. There it seems to have been discovered probably in every instance by the activity of its gland during lactation, and the discomfort caused by the flow of milk. In all, five cases of axillary mamma are on record, according to Leichtenstern. One of them came under his own observation (*loc. cit.* page 254). It occurred in the left axilla only, and was associated with another supernumerary nipple below and within the normal of the same side. There are still three other situations in which accessory mammæ are said to have been found, namely, the back (in two instances), the acromion (in one case), and the outer aspect of the thigh (in one case). Leichtenstern has examined the literature of these cases with the greatest care, and accepts them as trustworthy. Credit especially is due to him for having discovered what evidence there may be for the view, which occurs "in almost all

[1] *Dublin Quart. Jour. of Med. Sc.* vol. xxix. p. 109, Feb. 1860.

text-books of pathological anatomy," and is mentioned by Darwin,[1] that supernumerary breasts have been observed in the *groin.* Leichtenstern has found that the original case on which this general assertion has been founded is not a case of inguinal mamma at all, but a case of supernumerary mamma on the outer aspect of the left thigh of a woman. It was situated 4 inches below the trochanter major, and secreted milk. There is, therefore, no true instance on record of inguinal mamma. The instance of "acromial" accessory mamma is recorded by Klob (*Zeitsch. d. K. K. Ges. d. Aerzte zu Wien*, 1858, N. F. i. No. 52, S. 815). It was situated on the left shoulder of a man, just over the greatest prominence of the deltoid, with a milk-gland as large as a walnut, about the true nature of which there was no question.

The two cases of dorsal mammæ are derived by Professor Leichtenstern from the following sources:—1. Ch. F. Paulinus (*Observat. Medico-physic Select.* in the *Miscell. Curios. Academ. Med. Phys. Nat. Curios.* Dec. II. Ann. iv. page 203, Appendix): "Rustica fœmina e comitatu Winzenborch præter duas in loco ordinario adhuc duas alias ejusdem quantitatis et qualitatis mammas lacte fœcundas habuit e regione in tergo; jam tertia vice peperat gemellos qui ante retroque suxerunt." 2. Joh. Otto Helbig (*De rebus variis indicis, Obs.* 194, quoted in *Miscell. Curios.* &c., Dec. II. Ann. ix. and x. page 456, 11): "Bartholom. Salewsky nobilis Polonus, vir fide dignus in insula Macassar (veteribus Celebes) mulierem vidit, quæ mammas suas in dorso habens, eas sub axillis protractas infanti dabat, et firmiter asserebat integroc onsanguinearum suarum numero hanc monstrositatem esse propriam."

A few cases also are recorded of accessory mamma in the pectoral region, either directly below or directly without the ordinary mamma, or in the middle line. Some, at least, of these must be accepted with caution. With respect to the occurrence of supernumerary mamma in still other situations than those just mentioned, it only remains in this place to notice a remark of Professor Leichtenstern's upon *abdominal* mamma. That author says (*op. cit.* page 231)—"I know of no case in literature

[1] *Descent of Man*, 1877, page 36, *note.*

where accessory breasts or mammæ have been met with below the inferior border of the ribs, upon the abdomen." Amongst the cases collected by the writer, two certainly presented supernumerary nipples upon the abdominal wall below the border of the ribs. In one of them, a boy of eleven, a pair of supernumerary nipples were present, one below and within either of the ordinary mammillæ, but not quite symmetrically placed; and the left is described as "at a distance of 4¼ inches, distinctly upon the abdominal wall, about ½ inch below the inferior rib border." The other case (No. 8) is sketched in figure 1, where it will be seen that the right nipple is abdominal in situation. Besides these two cases definitely described as abdominal, three cases of supernumerary nipple were recorded in men, situated 6 inches, 6 inches, and 6½ inches respectively below and within the ordinary nipple; and it is, to say the least, exceedingly probable that in all these the abnormality was abdominal in position.

General Summary.

The general results of the present investigation may be summarised as follows:—

1. That 65 cases of supernumerary nipple were observed within a period of three years.

2. That of 315 individuals taken indiscriminately and in succession, 7·619 per cent. presented supernumerary nipple.

3. That 9·11 per cent. of 207 men examined in succession presented supernumerary nipple; and 4·807 per cent. of 104 women.

4. That in the great majority of instances the supernumerary nipple was single; that it was without exception situated on the front of the trunk below and within the ordinary nipple; and more frequently on the left side than on the right.

5. That the distance of supernumerary nipple from the ordinary nipple was very various, and that from the measurements of these distances a series of numbers may be obtained which may possibly suggest the unit of distance between the successive pairs of nipples in the original type.

6. That a supernumerary nipple, though frequently well-

marked, is more frequently small or deficient in one or more of its elements—papilla, areola, follicles or hairs.

7. That in no case was the supernumerary organ physiologically active; but that in a few cases supernumerary glands appeared to be present (in single women).

8. That inheritance was not traced in any instance.

9. That in more than one instance the anterior abdominal wall was the seat of the abnormality.

SIGNIFICANCE.

Strong though the temptation may be to indulge in speculation upon the origin and meaning of supernumerary mammæ and nipples, the writer will adhere to the resolution expressed in the introduction to this paper, and will rest content with the previous statement of facts. Those who are aware of the value of such facts to the science of biology, and those especially who are interested in the doctrine of evolution, will be better able to deal with the results just obtained than the writer, whose work lies in another direction. The whole subject will be found discussed at some length by Professor Leichtenstern in the valuable paper from which the writer has quoted so freely. Mr Darwin indicates the significance of supernumerary nipples in a single sentence—"On the whole, we may well doubt if additional mammæ would ever have been developed in both sexes of mankind, had not his early progenitors been provided with more than a single pair" (*Descent of Man*, 1877, p. 37, *note*). His other remarks upon this subject will be found in the following places:—*Desc. of Man*, 1877, pp. 162 and 163; *Var. of Anim. and Plants under Domest.* vol. ii. p. 57; and *Origin of Species*, 1875, pp. 189 and 397.

Post-scriptum.—Since this paper was written, eleven more instances of supernumerary nipple have been observed by the writer, chiefly in men.

ON THE ORIGIN AND COMPOSITION OF THE BODIES FOUND IN COMPOUND GANGLIA. By George T. Beatson, B.A. (Cantab.), M.D. (Edin.)

Last December I was asked by Professor M'Kendrick to examine a number of white bodies, not unlike grains of boiled rice, which had been sent to him by Dr W. Donovan of Whitwick, Leicestershire, who stated that they had been removed by him from a swelling on the front of a woman's wrist. This swelling, the size of a hen's egg, was of a soft elastic character, apparently contained fluid, and had first shown itself about seven years ago. It continued to increase in size, when it was opened by a surgeon, and was found to contain thick blood. This procedure dispersed the tumour until two years ago, when it reappeared, and as it was growing larger it was opened by Dr Donovan in November last, when a number of white bodies escaped along with some bloody fluid. The swelling had never at any time shown any signs of inflammatory action, nor had it ever been painful.

On inspection, I recognised the bodies as those commonly found in compound palmar ganglia, and termed by Wagner in his Pathology "corpora oxyzoidea." There were about two hundred of them, and they were of various shapes—pyriform, oval, and round, and some of them were clustered together in small masses. Placed in a beaker of distilled water they sank to the bottom of the vessel, but no change was observed in them even after some hours of immersion in the fluid. In colour they were white, and, as I have said, in appearance they were not unlike grains of boiled rice, but they varied very much in size. To the feel they were soft, elastic, and spongy, and it was not easy to make a transverse section of one of them, as it sank under the knife. When the section was completed it appeared as if there was a round pearly-coloured nucleus that could be picked out by itself, while the remainder of the body was composed of concentric laminæ, and was surrounded by a tough but elastic capsule.

Such being the naked eye appearances of these bodies, I proceeded to make some further examination into their structure and composition, first by means of the microscope, and then by subjecting them to some chemical reagents.

Freezing one of the bodies that had been steeping in the distilled water, I made sections of it, and on mounting one of these sections in glycerin and holding it up to the light there were two points to be noticed. The first one was that there was a distinct capsule surrounding the section, and the other was that the material in the centre of the section was denser and firmer-looking than that at the periphery. Placing the section under a low power of the microscope, nothing definite in the way of structure could be made out. The outside edge and the central part were similarly dense and compact, while the portion lying between them was composed of a reticular and finely-fibrillated kind of tissue, the alveoli in this reticular tissue being not unlike those of the lung. The high power of the microscope revealed the same condition of things, and no trace of fat cells, or cartilage cells, or cell nuclei could be anywhere detected. Some sections that had been placed in logwood and in picro-carminate of ammonia solution were next examined under high and low powers of the microscope, but the only thing apparent was that the periphery and central part of the section, together with the trabeculæ forming the walls of the alveoli, were deeply stained with the colouring material.

I then subjected some of the bodies to different chemical reagents, with a view of ascertaining the nature of the substance composing them. The first test employed was that of nitric acid and ammonia, and with it I obtained the xantho-proteic reaction, which is one of the most sensitive we possess for indicating the presence of a proteid or albuminous compound. Having next found that boiling one of the bodies in distilled water had no effect on its solubility, and only seemed to make it more contracted and less spongy than before, I placed another of them in equal parts of glacial acetic acid and water. The result of this was that it very soon became quite transparent and swelled up, and this gelatinous appearance remained even after boiling. Such was not the case when liquor potassæ was used instead of the glacial acetic acid, for, though the body became gelatinous as

in the previous test, on applying heat it was entirely dissolved, and the resulting fluid had changed, its characters being now of a brownish-yellow colour. I next tried the effect of nitric acid. On placing one of the bodies in water to which a few drops of strong nitric acid had been added a very strange effect was produced. In a short time the external portion became clear and transparent, while the centre was seen white and opaque, forming as it were a nucleus, and in this condition the body as it lay in the fluid was not unlike a frog's blood-corpuscle. Boiling had no effect on these characteristics. That this central part was not really a nucleus was shown by cutting one of the bodies into portions and putting them into the same solution, when this apparent nucleus formed in the centre of all of the portions. If, however, pure concentrated nitric acid was used instead of a weak solution of it, no such changes were produced, and, on boiling, the body shrank up, became of a reddish-brown colour, and eventually dissolved, the liquid turning to a yellowish colour.

In addition to using these various reagents, I placed three of the bodies in a platinum capsule and burnt them in the flame of the blow-pipe. The ash that was left amounted to 8 milligrammes, and, treated by the usual tests, showed the presence in it of a salt of lime.

From the history of the swelling and from its situation it was evidently a compound palmar ganglion, or tumour connected with the flexor tendons of the hand as they pass from the front of the fore-arm into the palm in front of the wrist, in which situation they are enclosed in a canal formed by the anterior annular ligament, and their surfaces are invested by a synovial membrane to facilitate their movements beneath that ligament. As regards the rice-like bodies themselves, from their behaviour under the different reagents mentioned above, and from the microscopical characters exhibited by the section of one of them, it is clear that they are fibrinous in their nature, and consist solely of compressed fibrillating exudation, the result of some inflammatory action affecting the synovial membrane. They resemble entirely that class of loose bodies in joints which are formed by a condensation of fibrinous coagula, and which Rokitansky describes as being distinguished by their uniform smoothness throughout,

by their possessing a delicate albuminous investing membrane, and by their manifest arrangement in concentric laminæ. But while some of these bodies no doubt arose from flakes or irregular masses of fibrinous matter floating in the serum effused in the inflammatory process affecting the synovial sheath of the tendons, which masses, as Brodie long since pointed out, become in time of more regular form and shape owing to the motion and pressure of the contiguous parts, yet from the pedunculated shape of many of them it was clear that at one time they had been attached to the synovial membrane, just like the so-called vegetations on the valves of the heart. An opportunity was soon afforded me of verifying this point. My friend Dr Renton had a patient suffering from a swelling situated on the palmar aspect of the proximal phalanx of the index finger. He opened the swelling and evacuated a number of white bodies similar to those given to me for examination by Dr M'Kendrick, and found to be identical in all respects with them. As the swelling recurred and interfered with the usefulness of the finger, it was decided to lay it freely open and dissect away as much as possible of its walls. This was done antiseptically by Dr Renton, and it was found that the walls of the tumour were formed by the fibrous theca, lined with synovial membrane, which is attached to the lateral margins of the phalanx, and serves to retain the tendon of the flexor muscles against the flat surface of the bone. The synovial membrane lining this theca, as well as that surrounding the flexor tendons, was enormously thickened by layers of fibrinous exudation, and its surface was covered with growths perceptible to the naked eye, and of various shapes. Some were like flattened scales, others were split at their ends into filaments like a tassel, and others were club-shaped.

From this it is clear that there are two sources of origin for these rice-like bodies, either the irregular masses of fibrin which float in the serum, poured out in the inflammatory stage of the disease, or the fibrinous deposits which take place on the surface itself of the synovial membrane, perhaps in connection with the synovial fringes, which are villous processes of the sub-endothelial vascular connective tissue covered with endothelium, just as in the case of the valves of the heart the villous excrescences called vegetations are due to hyperplastic growths of the connec-

tive tissue of the valve itself, which readily cause a precipitation upon them of fibrin from the blood.

Lastly, it may be observed that the nature and origin of these bodies bear on the question as to whether fibrin ever becomes any further developed or passes into a higher form of tissue. Judging from these bodies it does not, for in them there is nothing to be seen beyond a low grade of fibrousness, and they indicate no organisation whatever. The same thing is observed in other cases where we have fibrinous deposits. Thus, with the so-called vegetations on the valves of the heart, to which we have just alluded, they may tend to contract and harden, and even become calcareous, but they never show any tendency to inherent growth. So also with the wall of an aneurismal sac. Although it is often lined with dense layers of coagulated fibrine, Simon tells us that he has never been able to detect the slightest trace of new organisation in these layers.

THE PHYSIOLOGY OF THE TURKISH BATH: Being an Experimental Inquiry into the Effects of Hot Dry Air upon Man. By William James Fleming, M.B., *Lecturer on Physiology, Glasgow.*

With the exception of a paper in the *Lancet* of May 20, 1876, by Dr J. C. Bucknill, and another read by Dr Cameron at the meeting of the British Medical Association in 1877, all accounts of the Turkish bath have been confined to general descriptions of the details of the process, and of the sensations experienced during its use. Except in these papers I can find no record of any attempts to measure with scientific accuracy any of the various powerful effects which it is universally acknowledged to produce upon the bodily functions. In the hope of determining by experiment the exact action of hot dry air upon man, I have for several years carried on a series of observations.

I presume that my readers are all acquainted with the details of a Turkish bath. If not, there are many books from which they can be learned—notably that by Professor Erasmus Wilson upon the subject. Suffice it to say, that the essential part of the process consists in the immersion of the body in dry air at a temperature varying from 130° F. to 200° F. for a considerable time (half an hour to an hour generally), and subsequent douching with cold water. The accessories of shampooing, &c., are non-essential.

Our power of tolerating very great heat, provided the air is dry, without injury or inconvenience, has long been known. Indeed, Drs Forsyth and Blagden more than a century ago submitted themselves to a temperature of 260° F. (127° C.) without great inconvenience.

All the experiments were made upon myself, invariably before dinner, say 4 to 6 P.M., and about two hours after lunch. They were performed in the spacious bath of the Arlington Swimming Club, Glasgow; and I may here mention, for it is an important factor, that this is heated by Constantine's system, which consists in an arrangement of stoves by which a constant current of pure air is drawn from the outside atmosphere, heated by passing

through a species of oven, and driven into one of the apartments of the bath with such force that it traverses the whole suite of rooms, parting with some of its heat in each, and ultimately passing out from the last into the air. By this means not only is the air for breathing, but also the air in contact with the skin, constantly renewed, so that a layer of watery vapour does not, as in all baths heated with stationary air, soon cover the body and convert the bath into a vapour one. The freedom from all feeling of oppression, even at very high temperatures, experienced in a bath thus heated is the best proof of the excellence of the system.

The temperatures at which the experiments were conducted were generally, an initial heat of about 170° F. for a few minutes, to produce diaphoresis rapidly, followed by a subsequent temperature of about 130° F. during the remainder of the time spent in the hot rooms. This, I believe is the best system for habitual bathers, as perspiration being once freely established in the hottest room, is kept active by the lower degree of heat.

What I set myself to investigate was the effect of immersion in this hot dry air,—

1. Upon the amount of material eliminated from the body in excess of the normal.
2. The alteration produced in the temperature of the body.
3. The influence upon the pulse rate.
4. The influence on the respiratory rate.
5. The alteration in the composition of the urine.
6. The composition of the sweat.
7. The arterial tension as shown by the sphygmograph.

We have now to consider the modes of making the experiments under each of the above heads, and the results obtained.

Weight.

1. First, as to the amount of material eliminated from the body in excess of the normal. It is evident that to estimate this it was necessary to ascertain the exact weight before and after the bath, and the quantity of water drunk during the time. For this purpose I employed a beam turning with ¼ oz. when loaded with 3 cwt., with which all the weighings were done.

As the time occupied by the experiments varied considerably, I have in the following table reduced the totals to loss per minute.

TABLE I.

Experiment.	Actual loss in Ounces.	Drachms.	Total time in minutes.	Loss per minute in Drachms.	Grains.
1	60	0	60	8	0
2	38	6	55	5	38 10/55
3	22	4	30	6	0
4	35	0	55	5	5 25/55
5	24	4	40	4	54
6	24	0	40	4	48

This gives an average total loss of weight of 34 ounces 1 drachm in an average time of 46 minutes 40 seconds, that is an average loss per hour of 44 ounces—per minute of 5 drachms 53 grains.

The amount of water drunk averaged 4 drachms 44 5/7 grains per minute, so that the excess of loss over water consumed is 67 2/7 grains per minute.

Seguin calculates the average normal loss by skin and lungs as 18 grains per minute.

Now, all this material must have been removed either by the skin or lungs, no doubt by both, and I fear it is impossible to estimate how much passed off by each of these channels. However, it is a fact of great importance to know that by these two channels can be eliminated in an hour more than 44 ounces of the constituents of the body—not much less bulk than is normally excreted by the kidneys in 24 hours.

No doubt the amount of the solid constituents is much smaller, although by no means inconsiderable; nevertheless, even if we consider what is lost as pure water, it is obvious that the interchange of such a quantity of fluid in the economy must produce, or at least determine important metamorphoses. In fact, the process may be fairly considered as a washing of all the tissues of the body from within outward.

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by the nose until, after the lapse of ten minutes, the cool room was again entered, and the thermometer read and noted. In this way as far as possible I avoided the direct action of the hot air on the thermometer, and I do not think that it can have been much affected either by the heat passing through the cheeks or from the nasal cavity. It is possible, although I tried to avoid this, that some small quantities of heated air may have entered the mouth from behind and affected the instrument. However, the regularity of the results obtained in many experiments militates against the probability of this source of error having produced much effect. The chart gives the average of a number of observations. I do not, however, vouch so much for absolute as relative accuracy of the figures, since from the peculiar construction of the thermometer it is probably not to be entirely depended upon. As the amount of alteration, rather than the actual temperature, is what we wish to discover, this is of less moment.

Thus we have a rise of 3·7° F. produced by the bath, and this highest temperature was always reached at the end of 50 minutes. On the few occasions on which the experiment was prolonged to 60 minutes, a tendency to fall during the last part of the time was observed.

It is worthy of note that in the experiments described by Dr Bucknill and made by Dr Duckworth Williams, the rise of temperature observed was 1·7°, and as the period of immersion in the cases recorded by them was always very short this coincides exactly with my own observation at the end of 10 minutes. As in Dr Cameron's observations the whole of the thermometer was not enclosed in the mouth, I think the higher temperatures he obtained are probably due to direct heating of the instrument.

Pulse.

The pulse follows much the same course as the temperature, but the variations are greater. Especially did the rate before the bath vary on different days. Besides, the effect of thirst was observed to be an acceleration of the pulse rate, which

[illegible] is probably due to [illegible]

CHART II.

[illegible]

CHART III.

[illegible]

[illegible] effect, followed by a [illegible], and after the bath [illegible] bath. This does not [illegible] by Drs Bucknill [illegible] referred to. They give

the average diminution in the respiratory rate as 4·2, which closely corresponds with my result, namely, a diminution of 4; but they make no mention of the subsequent rise which I always found. This is probably due to the short time they kept their patients in the bath. They, besides, merely state that the observations were taken during the profuse perspiration, and not the time after entering the hot room. The average rates of pulse and respiration before the bath were in my observations—pulse, 79·4; respiration, 22·5. That is a ratio of 2 to 7, somewhat higher than the normal. At ten minutes the rates were—pulse, 92·5; respiration, 20·8; a ratio of 2 to 8·8, which is nearer the normal; at fifty minutes, 115·5 to 25·4; a ratio of 2 to 8·6. The well-known difficulty of not altering the rate of breathing when counting it yourself may have introduced error into these figures, but on several of the occasions medical friends counted for me. Their estimations nearly coincided with my own, except in the initial rate; and as my own result was abnormally high, I have in the above calculations adopted theirs.

Sweat and Urine.

As the mutual relations of the constituents of the sweat and urine execreted during the bath are the most important parts of this branch of the investigation, they will best be treated together. The method adopted for procuring the sweat was the enclosure of one of the arms in an indiarubber bag, confined round the shoulder by elastic bands, and furnished with an exit tube, closed by a clip. By this arrangement about 2 oz. sweat could be collected during an ordinary bath. The urine was passed immediately before entering the bath, and again after complete cooling. The sweat thus collected was found to have an average specific gravity of 1006·3, and to be faintly alkaline or neutral. The urine after the bath had a greater specific gravity (12° of urinometer) than before the bath.

I have to thank Mr W. J. Mackenzie for the careful chemical analyses he has made of these fluids. From the small quantities I was able to place at his disposal, the estimation was necessarily confined to the principal constituents—chlorides and nitrogenous substances—which we presume to be urea. For the first of

these the process he adopted consisted in evaporation with a little nitrate of potash, ignition to destroy organic colouring matter, and precipitation with silver nitrate.

The urea was estimated by Russel and Wert's hypobromite solution.

The mean of his results stated per thousand is given in the following table:—

TABLE II.

SWEAT AND URINE IN 1000 PARTS.

	Urine before Bath.	Sweat.	Urine after Bath.
Chlorides, . . .	5·68	6·05	3·65
Urea, . . .	17·61	1·55	19·18

From this we see that the sweat contained more chlorides than the urine before the bath, and nearly double the amount present in the urine secreted during and immediately after the bath. Whether the abnormally small amount of chlorides existing in the urine (not much more than half the amount given by Vögel as normal) influenced this or not, further experiments on different individuals will be required to ascertain, and whether this diminution of the urinary chlorides after free action of the skin has any bearings on the well-known reduction in their amount which is found in pneumonia and other acute diseases seems worthy of clinical investigation.

The urea, on the other hand, follows a very different course. We have a considerable quantity in the sweat, and an increased amount in the urine secreted during and after the bath. The existence of urea in the sweat is doubted by many physiologists, and out of the three principal analyses of this excretion by Favre, Shottin, and Funke, Favre finds only 0·044; Shottin, none; Funke, 1·55, per 1000. The absolute identity of the latter with Mr Mackenzie's result is interesting.

The amount of urea in the urine before the bath is about normal. The increase in the urine after the bath is probably

due to the increased density of the fluid, and the high temperature which the body reaches—a temperature like that of fever.

Blood Pressure.

The difficulty of obtaining sphygmographic tracings in the bath was greater than I expected. I did not venture to expose a Mareys sphygmograph to the heat and moist handling necessary; besides, I doubt if it is possible to manipulate the smoked papers properly under the circumstances. The Tambour sphygmograph,[1] which I devised some years ago, gave some fair results, but even it was difficult to manage, and the effect of the heat on the indiarubber membranes may have somewhat altered the tracings. However, I think we are justified in concluding that for the first ten to fifteen minutes the force of the heart beat is increased, and that after immersion for about twenty minutes it becomes feebler. This is shown by the diminished height of the tracing. The rounding of the summit and decreased distinctness of the dicrotic notch seem to point to an increase of peripheral resistance, and perhaps to the injection of a smaller quantity of blood into the vessels at each ventricular contraction. The condition of the circulation seems to be a great dilatation of all the superficial vessels, and therefore a diminution of the quantity contained in the heart and deeper trunks. This probably produces a faster action of the heart, as the observations on the pulse show actually took place; but it appears to the author that the necessary result of great capillary dilatation is increase, not, as usually supposed, diminution of peripheral resistance. No doubt the opposite condition, capillary contraction, causes an increase of peripheral resistance from the greater difficulty of forcing the blood through the narrowed channels; but in the case of dilatation, the vessels contain an immensely greater mass of blood, and this mass must require a greater expenditure of force to set it in motion, so that increased peripheral resistance may arise as well from excessive distention as from contraction of the capillaries. It is probable that up to a certain point this is counterbalanced by the greater facility of flow from diminution of friction, but I conceive that when the

[1] See this *Journal*, vol. xii. p. 144.

increase of the capacity of the capillary vessels is large, and extends over a wide area, the opposite effect is the more likely to accrue. This, then, is the condition brought about by the hot air, in my case at least.

The trace after the bath was absolutely normal, while that obtained before the bath was one of decidedly low tension.

Conclusions.

To sum up, it has been shown that a very large quantity of material can be eliminated from the body in a comparatively short time by immersion in hot dry air, and although the greater part of this is water, still solids are present in quantity sufficient to render this a valuable emunotory process.

The temperature of the body and the pulse rate are markedly raised.

The respiration falls at first, but afterwards is less influenced than would be expected *prima facie*.

The urine is increased in density, and deprived of a large portion of its chlorides, while, if anything, an increase in the amount of urea is produced.

The principal effect upon the arterial tension seems to be an increase produced by the greater rapidity of the heart's action combined with the dilated, we may almost say gorged, condition of the capillary circulation.

From these conclusions we may deduce the following practical observations as to the use of the Turkish Bath in medicine:—

Its most important effect is the stimulation of the emunctory action of the skin. By this means we are enable to wash, as it were, the solid and fluid tissues, and especially the blood and skin, by passing water through them from within out. Hence, in practice, one of the most essential requisites is copious drinking of water during the sweating.

The elevation of the temperature, and more especially of the pulse-rate and blood-pressure, point to the necessity of caution in cases where the circulatory system is diseased.

Excessively long duration of the bath seems to produce more or less depression, as shown by the fall of pulse and temperature after fifty-five minutes. It is probable that the time at which

this occurs varies with individual idiosyncrasy. In my case, it is accompanied by a distinct feeling, which I can only compare to satiety.

The great use of the bath seems to be the power it gives us of producing a free action of the skin in persons of sedentary habit, or suffering from disease interfering with fluid excretion, and by its means I believe considerable elimination of morbid matter may also be brought about. Besides, and along with this, it is an efficient means, if resorted to sufficiently early, of relieving internal congestion, on the same principle and with much greater certainty than the usual diaphoretics; and in rheumatoid affections not only does it act in this way, but by the relaxation of muscles permits of passive movements, rubbing, &c. (shampooing), exercising a much greater influence than they would independently exert.

THE FORM AND STRUCTURE OF THE TEETH OF *MESOPLODON LAYARDII* AND *MESOPLODON SOWERBYII.* By Professor TURNER, M.B., F.R.S.

(Read to the Royal Society, Edinburgh, June 2, 1879.)

DESCRIPTIONS and figures of the skull of the curious Ziphioid whale, now known by the name of *Mesoplodon layardii*, have been published by Dr Gray,[1] Professor Owen,[2] Professors Van Beneden and Gervais,[3] Dr Hector,[4] and Dr Von Haast,[5] and the peculiarities in the form and arrangement of its two remarkable mandibular teeth have been pointed out.

During the voyage of H.M.S. "Challenger," three specimens of this rare Cetacean were procured, and have been placed in my hands for purposes of description by Sir C. Wyville Thomson. In the course of my examination of these crania, I have directed especial attention not only to the form, but to the structure of the teeth of this animal; and as no one, so far as I am aware, has given an account of their structure, I propose to do so on this occasion. Two of the specimens, both adults, were collected by Mr H. N. Moseley, F.R.S., at the Cape of Good Hope, the locality where the whale was first seen; the third, a young animal, was obtained by the same naturalist at Port Sussex, on the west coast of East Falkland Island.[6] The lower jaw, teeth and beak of one of the adult specimens were procured, whilst the other consisted of the skull without the lower jaw and teeth. The

[1] *Proc. Zool. Soc.* 1865, p. 358, and *Catalogue of Seals and Whales*, p. 358, where the animal is named *Ziphius layardii.* In the *Supplement* to the *Catalogue*, Dr Gray names it *Dolichodon layardi.*

[2] British Fossil Cetacea from the Red Crag in *Memoirs of the Palæontographical Society*, 1870, where it is named *Ziphius layardi.*

[3] *Ostéographie des Cétacés*, Plate XXVII. figs. 1 to 3*a*, which are reproductions of Owen's figures, but reversed in the copying. They adopt the name *Dolichodon layardii.* See description, p. 402.

[4] As *Dolichodon layardii*, or the Scamperdown whale, in *Trans. New Zealand Institute*, v. p. 166, Plate III. In vol. vi. of the same *Transactions*, Dr Gray calls this specimen *Dolichodon traversii.*

[5] As *Mesoplodon floweri* in *Proc. Zool. Soc.* 1876, p. 478, XLIV., where, however, Professor Flower points out, p. 485, that the skull of this animal does not specifically differ from that of *M. layardi.*

[6] These specimens are described in my account of the Cetacea collected by H.M.S. "Challenger," prepared for the "Reports" of the Expedition.

difference in size of the adult and young specimens may be estimated from the size of their crania, which in the young specimen was 25 inches long, in the adult 40½ inches.

As the study of the teeth in the young animal has thrown great light not only on the structure, but on the peculiarities of form of the adult teeth, I shall in the first instance describe it.

MESOPLODON LAYARDII.

The teeth of the young *Mesopolodon layardii* were imbedded in their sockets, one in each half of the lower jaw. Each tooth consisted of a small triangular denticle, which represented the crown of the tooth, and of a larger part, which for descriptive purposes may be termed the fang. The denticle projected outwards and slightly upwards from about the middle of the upper border of the fang. It was $\frac{7}{10}$ths of an inch in its basal diameter, and $\frac{4}{10}$ths from apex to base. The fang was homologous with the strap-shaped shaft in the adult tooth, but instead of being vertically elongated and strap-shaped, its longer diameter of 2 inches was in the antero-posterior direction, whilst its greatest vertical diameter to the base of the denticle was only $\frac{8}{10}$ths of an inch. Along its deeper border it possessed a cleft $\frac{4}{10}$ths of an inch wide, which led into the pulp cavity. On making a vertical section through the middle of the entire tooth, this cavity was seen to be prolonged almost as far as the apex of the denticle.

The free surface of the denticle was completely invested by a glistening white enamel. A thin vertical section was taken out of the middle of the tooth and polished for microscopic examination.[1] The cap of enamel was then seen to be of almost uniform thickness over the entire denticle, at the base of which it was somewhat overlapped by an up-growth of cement from the fang. When highly magnified the surface of section was seen to be marked by delicate bands, extending almost perpendicularly to the surface of the denticle, which indicated the rods of which the enamel was composed.

Subjacent to the enamel was a well-defined mass of dentine, which constituted the chief substance of the denticle. It was

[1] This and succeeding sections were kindly made for me in the "Challenger" Laboratory by my friend Mr John Murray.

traversed by undulating branched tubes, which radiated outwards from the pulp cavity, and were arranged with as much regularity as one sees in the crown of a human tooth. Where the branched terminations of the dentine tubes came into relation with the deep surface of the enamel, a layer of irregular, but somewhat stellate, spaces occupied the dentine matrix. These spaces corresponded in appearance with the so-called granular layer situated in human teeth, more especially in the fang, between the dentine and cement, and may be termed interglobular spaces.

The dentine was prolonged downwards into the fang, and with a simple lens could be traced almost as far as the edge of the cleft at its root, but it formed so thin a lamina in the greater part of its extent, as to appear merely as a line in the section. When highly magnified the dentine in the fang immediately continuous with that in the denticle was seen to contain the tubes arranged in a regular manner, but as the dentine was followed further into the fang, the tubes began to break up into irregular groups, then to be sparsely scattered through the matrix, and at last to disappear, so that in the lower part of the fang the dentine was represented by a translucent matrix, having indefinitely shaped granules irregularly scattered through it.

The fang of the tooth was invested by a yellowish brown substance, which was smooth on its surface in proximity to the denticle, but in the region of the cleft was fitted with shallow grooves and small foramina, so as to have a porous aspect. In the section this substance was seen to vary in thickness, its maximum being $\frac{1}{10}$th of an inch, and becoming thinner both towards the denticle and the cleft. To the naked eye it was divided into a superficial and a deep layer by a well-defined line. The superficial layer consisted of cement in which the lacunæ and branching canaliculi were large and distinct. The deeper layer was more opaque, and required a very thin section to determine its structure. It consisted of a granulated matrix traversed by numerous canals, which were for the most part arranged perpendicularly to the surface of the fang, so as to extend from the dentine to the cement. To some extent they branched, and adjacent canals communicated with each other.

The pulp cavity was lined in the greater part of its extent by

a well-defined layer, having a maximum thickness of nearly $\frac{1}{10}$th of an inch. This lining could be seen with the naked eye to extend into the crown of the tooth, reaching on one wall of the cavity to within $\frac{1}{10}$th of an inch of its apex, on the other to about $\frac{3}{10}$ths of an inch. It had a brown colour, and the surface next the pulp cavity was marked by numerous shallow grooves and small foramina. Examined microscopically this lining had essentially the same structure as the deeper layer of the outer covering of the fang. The canals were, however, of greater calibre in the inner lining, and passed obliquely from the surface next the pulp cavity to that next the thin layer of dentine. The minute foramina on the free surface of this lining were the openings of these canals. Although, to the naked eye, the dentine, which formed the apex of the pulp cavity, did not appear to have any of this substance in contact with it, yet, when examined microscopically, the part next the cavity was seen to be discoloured brown, and with its proper dentine tubes often indistinct, whilst it contained some tubes of a larger calibre.

The cement, as capable of recognition by the presence of lacunæ and canaliculi, terminated about $\frac{3}{10}$ths of an inch from the edge of the cleft-like opening of the pulp cavity, and previous to its termination became very thin. The structure which formed the wall of the cleft was directly continuous with the deeper layer of the outer investment of the fang, and with the substance lining the pulp cavity. It had a similar microscopic appearance, but the part next the cavity had, in addition to the obliquely-divided canals, many canals divided transversely. There can, I think, be no doubt that in the living tooth these canals had contained blood-vessels. In size they approximated to the Haversian canals in bone.

The question now arises, what is the nature of this very vascular substance, which formed the lining of the pulp cavity, and the deeper layer of the external investment of the fang. If one could have traced its development one would have had no difficulty in answering this question, as the several tissues of a tooth arise from definite structures. Thus the enamel proceeds from the enamel organ, the cement from the alveolo-dental periosteum, and the dentine, with its modifications termed vaso-dentine and osteo-dentine, from the pulp. The absence, however, of both

dentine tubes and lacunæ and canaliculi in the matrix, and the presence of vascular canals, leave it doubtful, from a structural point of view, whether it ought to be regarded as a modified cement or a modified vaso-dentine. This difficulty would have been increased if the layer situated in the fang between the cement and dentine had been the only one present, as from its position it might have belonged either to the cement or to the dentine. But as a layer of similar structure also existed next the pulp cavity, there can, I think, be little doubt that it had arisen from the pulp, and, notwithstanding the absence of dentine tubes, may be regarded as a modified vaso-dentine, to which substance also the deeper layer of the covering of the fang may be referred. This conclusion is supported also by what is known of the structure of the teeth of some fish in which the dentine consists of a substance destitute of dentine tubes, but possessing a finely-granulated matrix in which vascular canals ramify.[1]

When I received from Mr Moseley the lower jaw of the *adult Mesoplodon layardii*, only the left tooth was in its socket, the right had previously been extracted. The socket was situated at the juncture of the symphysis with the body of the lower jaw, but more of the tooth was implanted in the body than in the symphysis. The length of the extracted tooth was 14 inches, 6½ inches of which had been included in the alveolus, or surrounded by the gum. The breadth of the tooth, where it emerged from the alveolus, was 3½ inches. Each tooth consisted of a denticle proper and a strap-shaped shaft. The shaft was laterally compressed, and as it emerged from the socket, it curved obliquely backwards, upwards, and inwards, so that its inner concave surface had been in relation to the side and dorsum of the beak. As the summit of each tooth passed to the opposite side of the middle line, the two teeth crossed each other on the dorsum of the beak, and from the smooth appearance of the anterior border and inner surface of each shaft it is evident that they must have rubbed against each other, or against the beak, during the movements of the lower jaw in the act of opening the mouth. The shaft represents, though on a much enlarged scale, that part of the young tooth which I have named the fang.

[1] Owen, *Odontography*. C. S. Tomes, *Manual of Dental Anatomy*, p. 79, 1879.

The denticle proper projected almost directly upwards from the outer edge of the upper end of the strap-shaped shaft, where it became continuous with the anterior border. It was triangular in shape, it base being half an inch, whilst its diameter from apex to base was $\frac{3}{10}$ths of an inch. The base sprang abruptly from the shaft, and some irregular patches of a glistening white enamel formed its outer surface, but the enamel was not continued upwards to the apex of the tooth, which was formed of dentine. In Professor Owen's figure of the denticle of the tooth of the original specimen, whilst the enamel is apparently worn off the tip of the denticle, the base is represented as enveloped by a more complete layer than in this animal. It is also stated that the matrix, by which is obviously meant what I have called the shaft of the tooth, is calcified without enamel.

In the extracted tooth, the alveolar end was seen to be closed, and to terminate, as in Professor Owen's description of the original specimen, in a solid jagged border. The surfaces of the imbedded part of the shaft were grooved with irregular longitudinal furrows and of a brownish colour. The surfaces of the protruded part again were comparatively smooth and of a yellow colour. A longitudinal section was then made through the shaft from the alveolar border to the upper end close to the base of the denticle. The shaft was then seen to be solid throughout, except for a minute mesial chink $\frac{1}{10}$th of an inch long and admitting only a fine needle, which was situated $\frac{7}{10}$ths of an inch from the upper end of the shaft.

To the naked eye, the shaft consisted in the greater part of its length of an external cortical part investing a central band. The cortical part was of a dull yellow colour: at the alveolar end it formed a thin lamina on each surface of the tooth, but at and near the line of emergence from the gum it was $\frac{2}{10}$ths of an inch thick, and on the extruded part of the shaft it averaged about $\frac{1}{10}$th of an inch in thickness. The cortical layer consisted of cement containing well-marked lacunæ and canaliculi. In the centre of many of the lacunæ a minute solid particle was situated, apparently the dried and shrivelled mass of nucleated protoplasm which occupies the lacuna in a living tooth.[1]

[1] See figure 207, p. 756, of my *Introduction to Human Anatomy*, for an illustration of the contents of the lacunæ.

Sections through Haversian canals were occasionally seen in the cement, more especially in its deeper part. The surface of the section through the cement was marked by numerous lines placed parallel to each other and to the surface of the tooth, which gave it a laminated appearance.

In the alveolar part of the tooth, and in the larger portion of the protruded portion of the shaft, the cortical layer was in apposition with the central band, which had an opaque white appearance, and varied in breadth from $\frac{2}{10}$ths to $\frac{4}{10}$ths of an inch. This band was traversed by canals, some of which were continuous with those of the cement, though others were divided transversely or obliquely. The matrix between these canals had a granulated appearance. The opaque central band had, therefore, the structural characters of the modified vaso-dentine described in the young tooth.

The upper end of the shaft, in proximity to the base of the denticle, was more complex in structure, and consisted of several layers; *a*, the most superficial, consisted of cement, in which however no Haversian canals were seen. Immediately subjacent to *a* was the layer *b*, thicker than the cement, and of an opaque white appearance. It had the same structure as the central band of the shaft, and the chief vascular canals were directed perpendicularly to the surface of the tooth. The next layer, *c*, was from $\frac{1}{3}$rd to $\frac{1}{4}$th the thickness of *b*, and was even more opaque; some vascular canals were seen to pass at intervals from it into the layer *b*. Subjacent to *c* was the layer *d*, which was about equal to it in thickness. It was very translucent, and contained undulating and branched dentine tubes, which ran outwards to the layer *c*. In one or two places *c* was less opaque than usual, and could be seen to contain closely aggregated tubes, not unlike dentine tubes, in addition to the vascular canals already referred to: *c* may therefore be regarded as vaso-dentine, whilst *d* is pure dentine. As these two layers were traced from the summit to the sides of the shaft, they were seen to blend with each other: *c* lost its great opacity, the tubes of the dentine disappeared, and vascular canals occurred only at considerable intervals. About an inch from the summit of the tooth these layers ceased to be recognisable. Subjacent to the dentine layer, in the summit of the shaft, was the layer *e*, which formed the central portion of

this part of the tooth. It had essentially the same structure as the layer *b*, but the main stems of the vascular canals ascended almost vertically, so as to be divided longitudinally in the vertical section through the shaft. Many shorter canals, which had, doubtless, connected the vertical canals with each other, were, however, divided obliquely or transversely. Along the surface of apposition of this layer with the dentine, sections through a canal were seen, into which some of the vertical canals were traced. Below, where the dentine terminated, the layers *b* and *e* became blended with each other, and together formed the white opaque band in the centre of the shaft of the tooth, so that they, like it, had the structural character of the modified vaso-dentine. The minute mesial chink in the shaft already referred to was a space in the layer *e*, and represented all that was left of the pulp-cavity.

We may now proceed to inquire by what process the unprotruded tooth of the young *Mesoplodon layardii* assumes the remarkable form and structure exhibited by the tooth in the adult animal. It must be observed that no change takes place in the shape of the denticle or crown proper. In its size, however, there is a slight diminution in the adult, This is doubtless due to the friction to which the denticle would be subjected soon after it had projected beyond the gum, For when the growth of the tooth had proceeded until it projected beyond the mouth of the animal; it could have suffered but little from the effects of friction, as it is set at such an angle to the shaft as to be directed away from the animal's snout, and towards the water in which it swims, That the surface of the denticle does undergo some slight loss of substance after it is protruded beyond the gum is evident from the disappearance, to a large extent, from the surface of the denticle of the cap of enamel. We are to look, therefore, for an explanation of the mode of production of the peculiar form of the adult tooth to changes in the fang, by means of which it is converted into the strap-shaped shaft. These changes are due to an enormous growth of two of the tissues of the fang, viz., the cement and the modified vaso-dentine. As has already been stated, both these structures are present, though in proportionally small amount, in the fang of the young tooth, whilst they make up almost the entire mass

of the strap-shaped shaft of the adult. By their growth the pulp cavity is obliterated, except the merest rudiment near the upper end of the shaft. Similarly, the dentine which exists as a very definite layer in the fang of the young tooth is reduced in the shaft to a layer situated only at its summit in the adult tooth. By the growth of the cement and modified vaso-dentine, not only does the tooth protrude from its socket and the gum, but from the mouth, so as to curve around the side of the snout in the manner already described.

The cement undoubtedly owes its origin to the alveolo-dental periosteum, which will serve as a centre of formation of new cement so long as the growth of the shaft continues. It is not possible to speak so positively of the origin of the tissue which constitutes the opaque central band of the shaft. If it be, as I have surmised, a modified vaso-dentine, then one would have to look to the pulp for its seat of production, but if it be a modified cement, then it would arise from the alveolo-dental periosteum. In the latter case, therefore, almost the entire shaft would be of periosteal origin. The tooth differs most materially from the tusks of the elephant or narwhal, in which the pulp cavity is persistent, and the continuous growth of the tusk is due to the conversion of the pulp occupying that cavity into dentine.

In the original specimen from the Cape, described and figured by Dr Gray and by Professor Owen, the teeth were not so large as in this animal, in which, indeed, the teeth have attained a length greater than in any previously recorded specimen. Dr Gray states that the length of the anterior edge of the exposed part of the tooth of his specimen was 9½ inches, whilst in this one the same border was 10 inches to the base of the denticle, and nearly an inch more to the highest part of the shaft. Nothing is said by either of these authors of the teeth crossing each other on the dorsum of the beak, and in the front view of the teeth in the jaw (*c.* fig. 72) given by Dr Gray, the summits of the shafts are represented as touching but not crossing.

From Dr Hector's short account of the teeth in his specimen, which was caught at the Chatham Islands, and from his published figures (plate iii. figs. 1–5), it is obvious that his animal was younger than the one here described. The teeth in the New Zealand jaw are only 6 inches long and 3 inches wide, so that

they could have projected only at the side of the beak and not reached its dorsum. When the "Challenger" was at New Zealand, Mr Moseley visited the Wellington Museum, where Dr Hector's specimen is preserved, and made a careful comparison of the jaw and teeth of the Cape specimen with those of the animal from the Chatham Islands. He has most courteously placed his notes at my disposal, and as they give a much fuller account of the characters of the teeth of the New Zealand specimen than has yet been published, I have much pleasure in incorporating them in this communication.

"When the anterior margins of the teeth in the two specimens at the spots where they cut the alveoli are placed accurately side by side at the same level, the posterior margins of the teeth in the New Zealand jaw reach back, and correspond in sweep of curve, exactly to the vacant alveolar spaces, which are conspicuous immediately behind the teeth in the Cape jaw. The teeth in the New Zealand specimen are thus inclined at a less angle than they are in the Cape one, and it appears that the teeth as they increase in age and length become tilted up towards the vertical, leaving vacant alveolar spaces behind them. Possibly they are dragged up by attempts to open the jaw after they have overlapped. In the New Zealand specimen the dentinal caps (my denticles) are about twice as large as in the Cape one, and proportionately thick and stout. In both, these caps are, when the teeth are *in situ*, almost vertical in direction, having thus, curiously enough, the original direction which they had when within the young alveolus, notwithstanding the curving of the hypertrophied fangs. In the New Zealand specimen the fangs being little curved, the caps are thus almost parallel to the fangs, or only slightly inclined outwards from them, whereas in the Cape specimen the caps are directed at right angles to the fangs, which, towards their tips, are so bent as to be almost horizontal. The alveolar regions of the fangs present in both specimens a similar series of ridges terminating in denticulations. The tips of all the denticulations are closed in the New Zealand specimen, and there is no trace of a pulp cavity, notwithstanding that the animal may be assumed to be young and with its teeth yet to grow, which it would do by a continuous addition from without by a periosteum which acts the part of a persistent pulp.

"The New Zealand teeth are much less curved than those from the Cape. If the dentinal caps are placed in apposition and parallel to one another, the younger New Zealand teeth are seen to be nearly two and a half times as broad as the older teeth from the Cape at the place of attachment of the caps of dentine. In each case the cap is placed on the anterior corner of the somewhat square-ended tooth, hence a large portion lies behind the cap in the New Zealand specimen, and but a small portion in the one from the Cape. On the anterior margin of the New Zealand teeth are semilunar excavations,

cutting into their substance and evidently caused by wear. The inner more spongy substance of the tooth being exposed it has decayed somewhat, leaving a harder external layer a little prominent. This decay is probably a *post mortem* occurrence. In the Cape specimen there is no trace of this wear, or a very slight depression may possibly mark it.

"The dentinal cap of the tooth in the New Zealand specimen is marked by grooves passing in an inclined direction from apex to base. Similar grooves are to be seen in the tooth of the young specimen of *Mesoplodon hectori* in the Wellington Museum, the tooth being divided by them into three lobes, a central and two lateral, on the inner face. The adult New Zealand specimen shows the same form in its dentinal caps, the lobes being on the inner face, and a pair of teeth of the same species from the Chatham Island, preserved in the Museum, show the same form also. In the teeth of the young *M. hectori* the pulp cavity is still open as a slit-like cavity, showing internally numerous fine ridges, which are apparently the commencement of the denticulations of the adult tooth."

In the skull described by Dr Von Haast, the length of the anterior edge of the exposed part of the tooth was 8·74 inches, and the anterior edge was not worn away; but both in it and in the Chatham Island specimen, described by Dr Hector, a sufficient space existed between the upper ends of the pair of teeth to allow of the beak to pass, when the animal opened its mouth. Dr Von Haast states that the animal was a full-grown male, and from the ossification of the epiphyses he judges it to be of mature age.

The tooth of a Ziphioid cetacean, from Little Bay, Sydney, figured by Dr Gray,[1] which he regarded as a new genus, *Callidon*, but which Mr Krefft, who obtained the specimen, named *Mesoplodon Güntheri*, closely approximates, in the relation of the denticle to the fang, to the tooth of the young *M. layardii* described in this communication. It differs, however, slightly in the shape of the fang, which in the Little Bay specimen is more elongated than in my specimen, so that the tooth is a little larger. There is nothing, however, in this character to found specific, still less generic, distinction on, so that I regard it as supporting Professor Flower's opinion that the Little Bay cetacean is an example of *Mesoplodon layardii*.

The Little Bay animal is said to have been 18 feet in length, which is also stated to have been about the length of the

[1] *Annals of Natural History*, 1871, vii. 368.

specimen described by Dr Von Haast. The animal from which the adult teeth described in this communication were procured was said to have been from 16 to 18 feet long, and both in it and in Von Haast's specimen the teeth had protruded so as to form large tusks, whilst in the Little Bay example and the one from the Falkland Islands, which was 14 feet long, the teeth are rudimentary in size. Now, as the Little Bay and Von Haast's animals were of about equal length, and as Von Haast's specimen, with well-developed teeth, was determined to be of the male sex, it is not unlikely that the Little Bay and Falkland Island specimens were females, so that the presence of well-developed tusks in the skull of *Mesoplodon layardii*, and it may be in the other Ziphioid cetacea also, is probably a character of the male sex.

MESOPLODON SOWERBYII.

The structure of the tooth of the *Mesoplodon sowerbyii* has already been described by Professor E. Ray Lankester from a tooth in the skull of the adult male specimen preserved in the Oxford University Museum.[1] The tooth I am now about to give an account of is from a much younger specimen, the characters of the cranium of which I recorded in the *Transactions of the Royal Society of Edinburgh*, 1872, vol. xxvi. In many of its characters this tooth differed considerably from that described by Professor Lankester, which is in all probability due to the difference in age of the two specimens,—and it may be to a difference in sex.

The two teeth of the young *M. sowerbyii* were embedded in their sockets in the lower jaw, out of which only the apex projected. Each tooth was laterally compressed and triangular in form. Its vertical diameter from base to apex was 2 inches, its antero-posterior diameter along the base $2\frac{1}{10}$th inches. The anterior border was longer and more oblique than the posterior, so that the apex of the tooth was directed upwards and backwards. There was no sharp demarcation into crown and fang; although a sinuous slightly raised line, half an inch from the apex, seemed to mark off the crown from the fang, and probably indicated where the gum had embraced the tooth. The outer

[1] *Transactions Roy. Microscopical Soc.* printed in *Quart. Journ. Microscopical Science*, vol. vii. 1867.

surface of the tooth was smooth, except near the base, which was marked longitudinally with shallow furrows; it was of a dull whitish-yellow colour.

About the middle of the elongated base was a narrow chink, which had evidently at one time extended along its whole length, but in course of time had become almost entirely closed. When a vertical section was made through the middle of the tooth, this chink was seen to communicate with a pulp cavity, which extended to $\frac{4}{10}$ths of an inch from the apex of the tooth. Near the base of the tooth the cavity was so contracted that the opposite walls were almost in contact; but in the middle of the tooth it dilated into a well-marked cavity.

A thin vertical section was then cut out of the tooth from base to apex, and prepared for microscopic examination. Under a low power the tooth was seen to consist in its greater part of dentine, which formed the wall of the whole of the pulp cavity, except at the root end of its contracted portion. In the upper third of the tooth, the dentine tubes radiated in a very regular manner from the pulp cavity outwards; but in the lower two thirds, they were broken up into clusters and tufts, and sometimes irregularly scattered throughout the dentine matrix. The surface of the section through the dentine was marked by contour lines parallel to its surface, which expressed the primary curvatures of the dentine tubes. But, in addition, a line of interglobular spaces lay in the substance of the dentine, parallel to these contour lines, and about midway between the most external of them and the exterior of the dentine. This line of interglobular spaces did not pass in one direction much beyond the apex of the pulp cavity, but in the other it extended some distance into the fang.

The dentine in the crown was invested by a thin layer of substance which had the position and relations to the dentine of a layer of enamel. It extended as far down the tooth as opposite the apex of the pulp cavity, where it was overlapped by the cement; but at the very tip of the tooth it was absent, having apparently been worn off. The characteristic enamel structure was not so definite in it as in the corresponding layer on the crown of the young tooth of *M. layardii*, but in thin

sections it was seen to be traversed by fine lines extending perpendicularly to the surface of the tooth, which obviously indicated the direction of the rods of enamel. But the exterior of the crown did not have the brilliant white appearance so characteristic generally of the enamel.

The free surface of the fang was invested by a thin but definite layer of cement. Where the dentine was covered by the cement, a change in the structure of the dentine occurred. Vascular canals were seen to lie in it perpendicular to the free surface of the tooth and forming loop-like curves immediately subjacent to the cement. This portion of the dentine was, therefore, a vaso-dentine. As the cement and vaso-dentine were traced lower down in the fang, other modifications became apparent. The vaso-dentine acquired greater opacity from the increase in general distribution through it of minute interglobular spaces, with which the line of interglobular spaces already described in the upper part of the tooth became continuous. But there also appeared between the dentine and cement a definite layer, at first thinner than the cement, but increasing in thickness as it extended down the fang, in the lower part of which it equalled in thickness the cement and dentine together. This layer was readily recognisable to the naked eye from its opaque white appearance. It contained numerous branching and anastomosing canals, the chief of which lay perpendicularly to the surface of the tooth. The matrix between the canals was granulated. This layer corresponded, therefore, in structure to the modified vaso-dentine described in the teeth of *Mesoplodon layardii*.

To the naked eye, the wall of the pulp cavity had numerous hemispherical bodies projecting from its free surface. When examined microscopically, they were seen to be continuous with the dentine, for the dentine tubes were prolonged into them. The dentine formed, therefore, the wall of the pulp cavity in the greater part of its extent; but the wall of the constricted part of the cavity in proximity to the end of the fang, and at the sides of the chink-like opening in it, was not dentine, but consisted of the substance which I have named modified vaso-dentine. It was not, however, so regularly constructed as the layer between the dentine and cement, for the canals were few

in number in proportion to the matrix, and had no definite arrangement.

I shall now make some observations on the leading differences between the teeth of this young *M. sowerbyii* and the adult animal described by Professor Lankester. In the first place, the crown of the tooth of the adult projected (as I have ascertained from a measurement of a cast of the jaw presented by Dr Acland to the Anatomical Museum of the University of Edinburgh) $1\frac{4}{10}$ths beyond the edge of the alveolus, whilst only the tip of the tooth in the young animal projected out of the socket. The outer surface of the young tooth was almost uniformly smooth, and not rough and knotted as in the adult. The pulp cavity, instead of being almost equal to the entire length of the tooth, was restricted in the adult to a small space in the crown, the rest of the tooth being solid. In this respect the adult tooth of *M. sowerbyii* approximates to what I have described in the shaft of the tooth of the adult *M. layardii*. The early stage of the closing up of the pulp cavity is to be seen even in the young *M. sowerbyii*, in which almost the whole of the cleft at the root of the fang is closed, and the walls of the adjacent part of the pulp cavity are closely approximated to each other. The enamel has evidently been worn off the crown of the adult, for Mr Lankester makes no reference to it. The dentine in the adult is confined to a small conical cap at the apex of the crown, and to a very thin layer extending about half-way down the tooth, instead of, as in the younger tooth, forming the larger proportion of its substance. The great bulk of the adult tooth was made up of cement, osteo-dentine, and of a substance which Mr Lankester calls globular matter. The cement was evidently considerably thicker in the adult than in my specimen, and the osteo-dentine and globular matter together formed a large proportion of the adult tooth. In the younger tooth, well-marked vaso-dentine was present, as already described, but I could not say that I recognised any definite osteo-dentine. The material which I have named modified vaso-dentine was also present in considerable quantity, and in its opacity it corresponded with the globular matter of Mr Lankester. In its structure, however, it appears to differ, for he describes the globular matter as having "no structure excepting an indistinct botryoidal character visible

with a low magnifying power." "The amorphous matter at length shades off into the dentine, numerous distinct, minute, 'interglobular spaces' becoming more and more distinct as one recedes from the opaque stratum, and their number diminishes." It is probable that this globular matter may represent in the adult the modified vaso-dentine of the younger tooth, for the numerous vascular canals which the latter contains may become obliterated through an extension of the process of calcification, so as to give it the more solid character present in the fully-formed tooth. In the granulated matrix of the younger tooth an appearance was not unfrequently seen which might have been described as interglobular spaces.

From Professor Flower's description of the structure of the teeth of *Berardius arnouxei*,[1] it would appear that in that ziphioid the teeth are very similar to those of the adult *M. sowerbyii* described by Prof. Ray Lankester.

The observations which I have now recorded on the non-erupted teeth both of *M. layardii* and *sowerbyii* prove, that in the earlier stages their structure does not differ materially from the ordinary type of tooth one meets with, say in the human or carnivorous jaw, the crown being covered by enamel, the fang by cement, whilst the great body of the tooth consists of dentine, in which is a well-marked pulp cavity, communicating with the exterior by an aperture at the root of the fang. The exceptional character which these teeth exhibit in the erupted condition is due to the disappearance of the enamel from the crown, to the cessation in the development of the ordinary dentine, to the excessive formation of osteo-dentine, of modified vaso-dentine, and of cement, by means of which the pulp cavity becomes almost obliterated, and the fang assumes dimensions which, in the case of *M. layardii*, lead to the production of a tooth having the very remarkable form and relation to the beak which I have described.

[1] *Trans. Zool. Soc.* viii. 223.

ON THE ELEMENT OF SYMBOLIC CORRELATION IN EXPRESSION. By Professor CLELAND, M.D., F.R.S., *Glasgow.*

THE very use of the word expression implies a relationship between mind and body; for that which is expressed is a condition of mind, and that by which it is expressed is a condition of body; while the problem remains for both the naturalist and the metaphysician—By what means do movements of the body, or more widely, conditions of matter afford an index to conditions of the mind?

Expression may be said to be conveyed through the medium of the senses of sight and hearing. The other senses may be left out of consideration; for flavours and odours, however far-reaching their effects on the percipient, have no utility whatever in directly determining conditions of other minds, and the sense of touch refers to forms and movements better determined usually by sight. By the blind, forms and movements are appreciated through touch, which by others are more quickly perceived through the medium of vision; and in the case of the deaf, visible signs may be made to serve a purpose better fulfilled by words when words can be heard; but it remains true that expression is a mechanism of forms, appreciable movements, and sounds, and that these are most generally conveyed through the portals of eye and ear.

Thus the problem of expression as I have defined it involves the whole study of the origin of language, and the same gulf has to be bridged over in determining how meanings have become attached to words as in determining how they are attached to arrangements of feature and gesture. But the origin of the primitive symbols in speech is so obscure, and the interaction of circumstances so complex in the elevation of them into languages, and in determining the differences and changes of these, that one can hardly expect as yet any further light to be thrown by philology on expression by feature and gesture than that which is afforded by the mere recognition of the fact that language is a

lower lip upwards to aid that closure of the mouth by which is expressed a resolve to resist, accompanied with an assertion of superiority,[1] it happens that those muscles render the integuments of the chin more prominent; and if they were sufficiently strong, and if the integuments to which their fibres descend were adherent to the bone, their habitual action would increase the mental prominence; but both they and the other muscles of the face attached to the chin are far too small for the wildest fancy to suppose that they can possess such an influence; therefore their action, instead of affording an explanation of the chin, rather exhibits a parallel problem in expression.

Another very striking illustration of the suggestion of mental character by permanent bodily form is to be obtained thus:—Taking a profile sketch, leave the features unaltered, but make additions or subtractions from the occipital region and back of the neck by changing the line descending from the position where the occipital and parietals meet, or from a lower point. Grave subtractions from the part so bounded become incompatible with the expression of mental stability long before they are carried to such an extent as to be anatomically improbable; but it must not be forgotten that the change so simply sketched implies the gravest alteration in the form of the brain and skull in their whole extent. Here, then, we have an instance of change of expression produced by the altered form of parts whose primary function is certainly not one of expression, and thus contrasting in a marked way with the changes producible by form of chin. In the present day, however, the theory of Gall and Spurzheim is justly exploded; and I make bold to repeat what I have already stated elsewhere, that the vague and helpless notions of localisation of mental functions in different parts of the cerebral hemispheres, so fashionable with so-called "medical psychologists," have no support from the facts of comparative anatomy, pathology, and experiment, all of which show that the hemispheres have a function common to the mass of their grey matter, so far as thought is concerned. Therefore,

[1] In some exceptional instances the closure of the mouth, even in ordinary conversation, is completed by the *levatores menti*, as if the upper lip were too far removed from the lower for the two to meet by the mere action of the inferior fibres of the orbicularis.

it would appear that differences of shape of head, not involving differences of cranial capacity, when they indicate differences of mental character, have a purely physiognomic value perfectly similar to that of differences of features of the face. We may even go further, and admit that it is probable that many of the statements of the followers of Gall have a large amount of physiognomic truth although their theory is utterly wrong.

These remarks are, I think, sufficient to illustrate that in the expressiveness of permanent forms of the body a class of phenomena exists, not to be explained by reference to the "three principles" which appear to Mr Darwin "to account for most of the expressions and gestures involuntarily used by man and the lower animals under the influence of various emotions and sensations," viz.: "Serviceable associated habits," "the principle of antithesis," and "the principle of actions due to the constitution of the nervous system, independently of the will." [1]

I might have alluded more particularly to those forms which depend not on the skeleton but on the soft parts, giving the presence or absence of chiselling to the features; the term chiselling indicating curves such as suggest a firm material moulded into shape, as contrasted with those into which soft pulp might gravitate. But it may well be answered that such modelling being pleasant to the eye is inherited by artificial selection, and that, though on this account more common in the educated classes, it may be largely present in the absence of grace or culture of mind or heart, while in other instances these latter may be present and modelling of the features absent. A fair argument might be sustained that the circumstances favourable to moral and mental selection are often coincident with those favourable to physical selection; and that, apart from this, it is natural to associate the pleasant in mind with the pleasant in body, forms noble on account of mere physical harmonies with nobility of moral description, even though the two things may not be associated in the external world. Yet there are probably few who will doubt that if two children of the same parents, closely resembling one another be taken, the one left in neglect, the other subjected to educating influences, the differ-

[1] Darwin, *Expression of the Emotions*, p. 28.

ence of treatment will be likely to tell on the moulding of the features.

Expression of the Emotions.

The element in expression of emotion, whether by gesture or feature, which appears to me to be the most important has often been entirely overlooked; and although it seems to have been largely present to the mind of Piderit and of Gratiolet,[1] yet the rationale has not been effectively expounded, and we see one of the most elaborate and ingenious writers on the subject, Mr Darwin, throwing it altogether aside.

I shall now try to put it in definite form. To this end, I observe first, that words indicating position and quantity represent ideas relating to both the physical and mental world. Secondly, emotions expressible by such words are indicated by the attitudes, gestures, and movements of body expressed by the same words. Thirdly, the same principle is applicable to movement of feature.

1. For the sake of clearness it may be well to discuss the first of these propositions separately. The words useful for our purpose by referring to both physical and mental conditions are such as the following:—Those expressing height as—upward and downward, ascent and descent, elevation and depression, superiority and inferiority, rise and decline or fall, over and under; those expressing other directions, as—forward and backward, advance and retrogression, before and behind or to one side, direct and roundabout, straight and oblique; those expressing distance, as—far and near, approach and separation, attraction and repulsion; words expressing magnitude, as—large and small, wide and narrow, expanded and contracted; words expressing resistance, as—strong and weak, hard and soft, firm and yielding; words connected with motion or rest, as—quick and slow, tension and relaxation. The connection between the physical and other meanings of these words is in most instances not far to seek. No doubt at first sight it may seem puzzling to find anything in common between moral elevation and physical elevation or mere distance from the earth's surface, and one may look on it as remarkable that in the ideas of all men the two

[1] Darwin, *loc. cit.* p. 6.

things are associated, and are so by a link independent of the peculiarities of individual languages, so that one is led to suspect that the bond is not only universal but necessary; and a similar difficulty may be felt at the application of such words as "advance," not to movement in space but to conditions of other than physical description. But very little consideration will make such difficulties disappear. They do not exist in relation to many of the words enumerated above; for magnitude, resistance, and motion, three of the heads used in the enumeration, are obviously ideas not confined to objects in space, though primarily the words refer to physical objects, according to the general rule of words with a physical and metaphysical application. As regards words expressing distance, it will be noted that "near" or "far" remains the same idea, whether the degree of deviation from identity contemplated refers to time, space, or constitution; while attraction or repulsion is the mere tendency to passage from one degree of nearness to another, whether in space or in constitution.

In such expressions as "advance" and "retrogression" we have still to deal with distance; only in this instance it is distance from a goal more or less distinctly imagined; while the character of the means adopted to reach a goal is expressed by such words as "direct" or "round about."

There remains only the metaphoric use of words referring to height to be explained of all the list with which we began. Here another principle comes into play: we have not to do with a common idea of various application, but with two distinct ideas associated by circumstance. Because the sky and the natural sources of light are above, because vegetable life attracts attention most by growth above the surface of the ground, because the visible products of putrefaction sink down and become buried over, because dead bodies fall, because in activity we stand up, and in rest lie down, and because a lofty position commands attention and gives physical advantages, therefore a host of associations grow up in the human mind, by which 'upward' represents the good, the great, and the living, 'downward' the evil and the dead. In the same manner, indeed, more directly, we associate impressions through the organs of sense with impressions from the moral world similarly pleasant or

otherwise, as in the case of sweetness, bitterness, brightness and gloom.

2. Emotions to which such words as we have been considering, have application, are indicated by the attitudes, gestures, and movements of body expressed by the same words. More shortly, the workings of the mind are expressed by attitudes, gestures, and movements of body of a nature correlative with them.

That which we like we desire to be near to, what we dislike we seek to avoid; but it is not merely on these accounts that we bend the body forwards and approach that which pleases us, while we retreat or draw our head and body back from what is offensive. In numerous instances such movements and gestures are made not from any notion of achieving a purpose, and still less from an inherited habit founded in their utility to real or supposed ancestors, but simply from the close connection subsisting between movement towards an object and mental attraction to it, or between movement away from an object and a feeling of repulsion. A similar remark holds good with regard to movement of the arms, which perform gestures of receiving and rejecting. It may be mentioned in passing that, so far as these are performed from the shoulder, they are accomplished respectively by the *pectoralis major* muscle, which might be termed the muscle of embrace, and the *latissmus dorsi* muscle, which might be called the muscle of rejection, a name which would express its action more accurately as well as more becomingly than that given to it by old anatomists. Lift the arm into the position which places the latissimus dorsi on the greatest stretch, and sweep it downwards and backwards, with the palm turned away from the body, and no gesture of the limb can more thoroughly express the putting away of something vile. Nay more, if the same movement be carried out also by the forearm and hand, the gesture begins with the palm in front of the face as if to conceal from the eyes what is loathsome, and passes from this to the removal of it altogether. Yet it is a gesture applied to the intangible and invisible; by it the cleric puts away false doctrine, and the fastidious sublimely brands a notion as vulgar. In like manner, slight movements of the arms express the hugging of an idea to the bosom when nothing but what is thoroughly unpersonal is thought of, and the fingers bend as if

to keep a something in the hand when nothing but delightful sentiment is concerned. Thus, one may frequently see among children at play, when an amusement is proposed, the right or more active arm thrown upwards and inwards towards the opposite shoulder, and the hand gently closed, while the word "come" is on the lips, and that when no removal to another place is intended. It is partly the expression of a wish for all to join in concert, partly it expresses the pleasure with which the object to be joined in is anticipated. Similarly, if an artist wished to express sympathy he would bend the figure forwards toward the object of the emotion, with the fingers stretched in the same direction, as if ready to help, and the palm probably inclined downwards, as if in token of protection, but not because there is anything actually to be covered by them.

In exercising authority the body is raised to its full height, because the moral attitude is one of superiority, and the hand may be brought down to indicate that opposition will be dealt with in the way which in the symbolism of language is expressed as "put down." Again, a speaker in explaining his views may bring the fingers of one hand down on the other, as if he were producing a visible object and placing it on his hand before you, or were pointing to a visible statement on paper, the downward movement not now giving the idea of destruction, but of that which is symbolically called "laying down" his propositions. Here the movement of the hand keeps pace with the success of the speaker's effort to put his ideas in words; the movement is arrested and the muscles tense, as in a state of mental tension he struggles with a difficulty, then as he overcomes the difficulty down goes the hand, as everybody knows, with energy parallel to that which he wishes to give to his statement.

It may be doubted if there are any gestures to which the principle of symbolism, which I have attempted to illustrate, does not apply. True, movement upwards, downwards, forwards, and backwards, with quickness or slowness, tension or relaxation, form but a small number of elements of gesture compared with the varieties of mental condition expressed, yet there are combinations, adjustments, and accessories which give them a wide range of expression. Take the condition of relaxation, for example; it may be seen in enjoyed repose, or in sorrow, weariness,

or despair. But, keeping feature entirely out of the question, in enjoyment of repose the attitude exhibits careful selection with a view to comfort, which in the excess of sorrow or despair is entirely absent. In despair the body is thrown back, and causes its relaxation to indicate the uselessness of having anything further to do with that which is before the mind's eye; in weariness it turns to one side as if change could alone give relief from utter lifelessness; while in sorrow the body is folded on itself as if the heart would nurse its own bitterness, and yield to prostration, with the world shut out. But especially is the direction of the eye the appropriate supplement of gesture, and its connection with this may fairly be taken into account before considering expression by the features. An erect carriage may be given to the body by haughtiness, conceit, the exercise of authority, or the presence of ennobling thoughts, but very different is the direction of the eye in these different circumstances. In haughtiness the upward head contrasts with the somewhat downward glance, indicating that it is the height pertaining to self which occupies the mind and which looks down on others; in conceit the straying of the eyes over the person, and the glancing about to take note of the effect on others, show how approbation is sought for; in command the glance is direct as of one who would bring his personality right into contact with those whom he would wield; but in ennobling thought the eye, as well as the body, is turned upwards as if both were governed by a power above them.

In kneeling in worship the idea is that of humiliation before a superior Being, and if the eyes are directed upwards, it is because the mind naturally associates the rule of such a Being over us with a dwelling above us; while if the hands are clasped or crossed on the breast, it is the natural conclusion of a motion of the arms towards one another as if in desire to receive. I venture to think that this is a more natural explanation of clasped hands than the idea of placing them in the hands of another in token of submission. But what I wish to attract attention to now is, that in humble attitudes the direction of the eyes is in harmony with the direction of the face; if the face be turned upwards the eyes look upwards; if downwards, the eyes look downwards; and the expression is very different both from

the contemptuous effect of an upward face and downward eyes, and from the downward face and upward eyes with their many variations, seeming, with one exception, always to convey an expression into which a concealed advance enters as a necessary element. The culprit sheltering himself by a lie, who has not mastered the base art of concealing the concealment which he practises, hangs his head over his secret, while he steals upward glances to see the effect which he distrusts; and if suspicion enters more largely into his feeling, he does not face you, but stands sideways, and, looking obliquely, betrays by the want of harmony between eye and attitude the duplicity which is within. On the other hand there are expressions delightfully gay in which a slight bend of the neck is combined with an upward glance; yet they have the element of slyness entering into their humour, or that equally innocent and slight suggestion of a secret taking the form of a confidence which seems to say, "You and I understand."

There appears to me to be one exception to the rule that a downward face and upward eye give the idea of concealment; and it is in mental absorption when the head happens to be bent forwards and the eyes staring into space. Yet it is an exception more apparent than real, the glance having less the appearance of proceeding from the face than of having quitted it altogether. What catches the eye most in such circumstances is the relaxation, the absence of expression, from the mind being too much occupied with its musing to devote attention to attitude or feature. The head only bends when the relaxation of the previous attitude allows it to fall forwards; and it falls as readily backwards when the attitude has been favourable to that movement. The eyes also are probably nearly in the position of muscular inaction. In the dead the position of the eyes is more turned upwards than they would be in looking directly forwards during life, and their strange stare seems to depend less on the perfect movelessness than on a slight divergence of their axes. Further, it is known that the condition of rest of the adjustments within the eyeball is when the focus is set for the infinitely distant, which requires the axes of the eyes to be parallel; and one may see in the stare of absorption that the eyes are parallel or slightly divergent, therefore probably with the muscles of the eyeball relaxed.

But enough, probably, has been said to illustrate the principle sought to be established, that attitudes and gestures, including movement of the eyes, have direction corresponding essentially with the emotions which they express.

3. The same principle is applicable to the expressions of the features. It is palpable that in feelings of elation the angles of the mouth are raised, the upper eyelid also is drawn well up, the eyebrows are lifted, though not sufficiently to produce the slightest wrinkle of the brow, and even the lower eyelid is raised, partly by contraction of fibres of the *orbicularis*, partly pushed by the rising cheek. Nor is elevation the only movement, but nature expresses the expansive feeling, the tendency of gladness to widen its scope, by an outward movement. The angles of the mouth spread more outwards than upwards, and as elation is carried further the mouth begins to open. The apertures of the eyes are not as capable as the mouth of outward enlargement; but to them also the appearance of greater breadth is given by the formation of lines spreading outwards and upwards from the outer angles. Nor is the nose, though less movable, quite quiescent: it is perceptibly broadened and shortened by the outward and upward movement of the alae. Thus this characteristically human expression is not confined to a single feature, much less the effect of a single muscle, after the fashion in which Duchenne[1] endeavours to demonstrate that various expressions are produced each by a particular band of fibres. The means are various, by which the results so harmonious in character, so similar in their symbolism, are achieved: here it is by the direct pulling of muscles, there by the accident of one part pushing another upwards, and by the wrinkling caused by an action having another primary object.

Under the influence of the depressing emotions the same parts are depressed which were raised in smiling; and the apertures of the face, the openings of communication with the world, are diminished as the soul retires from its disagreeable surroundings. The brows, the eyelids, the alae of the nose, but most of all the angles of the mouth, are lowered in all expressions of sadness.

But, in speaking of smiling and sorrow, I keep out of consider-

[1] *Méchanisme de la Physiognomie Humaine.*

ation altogether laughter, sobbing, and crying. They do not fall within the limits of actions principally explained by the natural correlation of physical movements and mental actions; they depend, probably, altogether on the mechanism of the nervous system. The nervous centres acted on by an excess of emotionare deranged; and it would require a far more intimate knowledge of cerebral function than has yet been arrived at to enable us to follow the details of the causation of the convulsions produced. Laughter, sobbing, and crying have the feature in common of convulsive breathing. In laughter, perhaps in symbolical connection with desire for the outflow of emotion, the expirations are accentuated and prolonged, and are, therefore, most obviously broken with convulsive quiverings; in sobbing, on the contrary, the inspirations are elongated and broken into a number of convulsive acts; while in the crying of children the true sobbing is mixed with a desire to announce their sufferings loudly abroad, and, therefore, the convulsive inspirations are followed by an unnecessarily long expiration, utilised, if I may use the expression, for the purpose of howling. But it is interesting to note that the extreme distortion of the face in the most violent crying is not dissimilar from that in the most violent fit of laughter; and an amusing illustration of this can be obtained by turning up Plate I. fig. 2 of Mr Darwin's work on Expression, which represents a little child with eyes shut and mouth open, evidently roaring. Cover with a card all but the face, and draw on the card the body of a fat old man lying back in his chair, and the child's face, without a stroke of change, will be converted into the bald head of the old man convulsed with laughter. How so? Simply because old men are more given to roar with laughter than to bellow like children.

There is another of Mr Darwin's illustrations with which a similar experiment may be made, namely, Plate V. fig. 1, a female head expressing disdain. Hide the neck, and make that head bend over a figure so drawn that the head shall have a droop in keeping with the direction of the eyes, and the expression of contempt completely disappears, giving place to one which is serious and quiet. The experiment, however, could not have been successful if the expression had been carried further by the curling of the upper lip. When contempt is expressed merely

by attitude, it is done, as I have said, by upward and backward motion of the head, and a glance in precisely the opposite direction. When the features aid the expression, they act on the same principle. While the angles of the mouth are free from all elevation, or are even depressed, in token of the depressing effect of the unpleasant, retreat upwards and backwards from that which excites disdain is indicated by the raising of a portion of the upper lip; and the expression once originated can be exaggerated by the drawing up of the lower lip and the chin by the *levator menti*, while the angles of the mouth are actually pulled down, so as to give it the appearance of an elongated object held down at the ends which one seeks to pull up from the surroundings which hold it. In the allied expression of disgust, the *levator menti* takes no part, while the depressors of the lower lip are more strongly contracted, because the idea is no longer to keep away from the objectionable notion but to get rid of the foul thing which has already entered. The same muscles come into play in getting rid of a bad taste, and language, travelling in a similar line to expression by feature, expresses the alliance by the word disgust. Darwin also, quoting Piderit, draws attention to the action of the nose, which gives the idea of getting rid of an offensive odour; but I think these writers are mistaken in imputing to the upper lip an action "so as to close the nostrils as by a valve." The upper lip is incapable of shutting the nostrils, and is not used in any animal for that purpose; and what we really do, in an unrestrained expression of disgust, is to raise and distend the nostrils, as if to give egress to an objectionable vapour which has already intruded, and forthwith we expire through both nostril and mouth.

Resolution is expressed mainly by the mouth, compressed lips indicating opposition to assault or entreaty from without, or the closing up of any tendency to yield from within. In the pout of discontent the angles of the mouth are drawn in as in all expressions of dissent, while the projection of the lips is in readiness for an expressive expiration rendered audible, it may be, by a labial, just as when the teeth and jaws take up the symbolic action instead of the lips, naturally syllables with dentals lie to hand. By what slight circumstances expression of features may be modified is seen by the very different impression

produced by a protruded and contracted mouth ready for an inspiration.

Hitherto I have made little mention of the muscles of the forehead. What Mr Darwin has written on the "grief muscles"[1] is exceedingly suggestive; yet I own that, to my mind, it falls short of explaining the phenomena which he so graphically depicts. The frown expresses displeasure by the descent and gathering together of the two eyebrows, and so far is in perfect keeping with the principle of symbolic correlation which I have tried to give prominence to. It occurs also in attempts to see distinctly external objects, helping to shade from dazzling surroundings, and concentrates the attention on a limited field; and, in exercising the internal perceptions when a difficulty is encountered, the forehead falls into the same condition as when a difficulty in distinguishing an object with the eye is met with. These explanations appear to me more satisfactory than to suppose that the frown is the relic of childhood's screaming,[2] the more so as in the worst cases of screaming in childhood the eyes are not protected by a frown at all, but by the violent closure of the lids by means of the *orbicularis*, so that the infantile frown is rather derived from the same source as the frown of the adult than the parent of it.

The formation of "rectangular furrows" on the forehead, with elevation of the inner part of the eyebrow, is more complex, and demands reference to the anatomy of the muscles. Undoubtedly we owe to Duchenne the knowledge, which anatomists ought to have perceived before, but did not, that the *pyramidalis nasi* is antagonistic to the central fibres of the *frontalis*. It is attached to bone below, while the more fixed attachment of the *frontalis* muscle is above. For a much longer time we have known the *corrugator supercilii* as an opponent of the *frontalis*, but the description of it is unsatisfactory. In the eighth edition of Quain's *Anatomy* it is described, according to the received mode, as proceeding "outwards and a little upwards." Luschka describes it as part of the *orbicularis*, and denies its power to corrugate the eyebrow.[3] Henle, highly elaborate, describes it as part of the *orbicularis*, and consisting "of two or three slips covering one another in such a way that those arising highest are the

[1] *Op. cit.* p. 181. [2] Darwin, *op. cit.* p. 225.
[3] Luschka, *Anatomie des Menschen*, iii. p. 365.

deepest, and pass most from a gentle upward slope to a transverse direction."[1] But he also describes as part of the *occipito-frontalis*[2] slips passing upwards from an attachment to the frontal process of the superior maxillary bone. So far as I can see by dissecting the *frontalis*, *pyramidalis*, and *corrugator* muscles from the deep aspect, a much simpler description would be more accurate, as well as more in accord with what may be made out by examining carefully the movements of the integument during life. I am disposed to describe together the muscular fibres passing upwards from the superior maxillary bone and inner end of the superciliary ridge as a sheet which widens as it passes upwards inseparably connected with the *frontalis*, its upper and inner fibres directed toward the frontal eminence, while its outer fibres form the part of the muscle usually bearing the name. In antique statuary the line of action of the moveable attachment of this muscle is sometimes indicated by a depression rising upwards and outwards high on the forehead, while the gathered integument is comparatively smooth. This is the actual line to which the action of the muscle can be traced on the living body in males with fleshy foreheads; and I have no doubt that this, unmixed with "rectangular furrows," was the outline of the horse-shoe of Sir Walter Scott in *Redgauntlet*. When this line is drawn downwards and inwards, the result will be to approach the upper attachments of the outer fibres of the *frontalis* so much to their inferior attachments that they will be deprived of the power of raising the eyebrow or wrinkling the forehead; and this I believe to be the anatomical reason why the outer parts of the eyebrows are depressed while their inner ends are elevated in the joint contraction of *frontalis* and *corrugator* muscles. On the other hand, the outer angles distinctly participate in the action when the brows are raised in expression of cheerful eagerness; and when I assume that expression I can feel that the *occipitalis* and *attrahens auriculam* are brought into action.

The raising of the inner ends of the eyebrows, while they are depressed in the rest of their extent, is a combination similar to the raising of the upper lip while the angles of the mouth are drawn down; and it often accompanies that action in expressing the acuteness of that petty vexation which is akin to disgust,

[1] Henle, *Anatomie des Menschen*, i. p. 143. [2] *Ibid.* p. 136.

and sometimes so named. Then, the expression travels up from the mouth to the forehead. And this brings to our notice that some expressions are more liable to be shown by the mouth, others by the eye and forehead, and only when they become intense do they invade the whole face. I believe that I shall be correct in saying that expression for the information of others is most liable to be made with the mouth, the organ of communication with the world; while expressions that betray thoughts unconnected with the outer world are most liable to begin in the eye and forehead. I take it that the transverse wrinkling of the brow is simply the expression of mental irritation by muscular contraction, such as occurs in the rest of the face, but confined to the forehead when the mind is thrown in on itself and not intensely excited. Thus it is proverbially the expression of care, and still more of despair. Hopelessness, I imagine, is the idea in Mr Darwin's mind, when he calls it the expression of impotence. Round both the mouth and the eyes, the muscles expressive of control are those which draw the parts together. When control is lost altogether, the radiating muscles have it all their own way; and therefore it is that the brow is transversely furrowed, the eyes staring, and the mouth wide open in terror. When control is sought to be exercised, and emotion pulls the antagonist muscles, the result is quivering, a quivering sometimes seen in the rectangular furrows on the forehead. Those furrows are most variable in meaning. In bright sunlight the frontal is employed by the will against the instinctive protective action of the corrugators. At other times the frontal takes the lead, and the corrugators try to counteract it, or an absurd trifle disturbs serenity, and twitchings take place out of harmony.

But I have sufficiently spoken of the subject which I have mainly sought to illustrate, namely, that the principal key to a great part of expression is the correlation of movements and positions with ideas. I shall only add that the correlation which I have sought to make plain is found elsewhere in nature besides the face of man. In the vegetable kingdom the flower is put in the place of honour; in the vertebrate animals, the nervous system, which, with the exception of the supraœsophageal ganglion had been inferior in the articulata, becomes superior, while in man the brain is superior in every sense.

AN INTRA-THORACIC LYMPHOID TUMOUR.

By Dr R. Hogarth Clay.

I am induced to place on record the following case, from its interest as an example of a rare form of intra-thoracic tumour:—

F. N., aged six, came under my care on the 29th of October 1878. He had been ailing for three months, complaining of languor, occasional pain in the left side, some shortness of breathing on exertion, and now and then slight dry cough.

On my first visit I found him thin and ill nourished, breathing rapidly and laboriously. On inspecting his chest, the left side appeared fuller than the right; the intercostal spaces of the lower part were bulging, and the measurement exceeded the right by one inch. There was absolute dulness on percussion, extending downwards from about an inch above the angle of scapula behind, and from the nipple in front. Over this dull region there was entire absence of breath sounds, of vocal fremitus, and vocal resonance. Both behind and in front, above area of dulness, the breath sounds were harsh, and the percussion note somewhat hyper-resonant. There were no moist sounds.

The right lung was normal. The heart was in its right place, and the sounds were normal. The temperature was normal Urine scanty, with an abundant deposit of pale lithates; no albumen. The patient lay persistently on the right (healthy) side; no œdema of any portion of his body. There was an enlarged and tender gland in left axilla, and a growth the size of a walnut, apparently glandular, in the region of the nipple of same side.

After remaining in this state for a week his breathing began to improve, the dulness on percussion and the bulging of intercostal spaces slowly diminished, and on measurement the left side of the chest was found to have decreased half an inch. This improvement continued, but in a few days his breathing again became so laborious and hurried that he could with difficulty take food. He had also occasional attacks of severe pain in the left side in front. The dulness on percussion in front slowly extended, till it reached quite to the clavicle, the whole left front becoming absolutely dull, with entire absence of breath sounds and vocal fremitus. The glands in the neck above the left clavicle became enlarged. Behind the physical signs remained almost unchanged. As the dulness in front increased the heart sounds became more distant, and were heard slightly more to the right of sternum. At times he had attacks of intense spasmodic difficulty of breathing, apparently from pressure on the recurrent laryngeal nerve, and occasional attacks of cough without expectoration. The diagnosis was tumour of the anterior mediastinum, and effusion into the left pleural cavity.

On November 20th, it was deemed necessary to use the aspirator, with a view to relieving the urgent symptoms, and about ten ounces of clear serum were drawn off. This gave slight relief to the general symptoms. The spasms of difficulty in breathing to a great extent ceased, but the severe pain in the side still occasionally recurred. It was with great difficulty he could be made to take food, and he became gradually thinner and weaker. The physical signs in front remained unchanged; the dulness behind increased. On December 12th the aspirator was again used, this time drawing off eighteen ounces of bloody serum, with hardly any relief. He had up to this time rested entirely on his right side, but now he changed his position, and preferred lying on the affected side. His left hand and arm became enormously œdematous. On December 28th, the symptoms becoming more urgent, twenty-two ounces of clear serum were removed by the aspirator, with but slight and temporary relief.

From this time to the date of his death, January 7, 1879, the physical signs remained unchanged. Gradually sinking, he died without a struggle. Three weeks before death large veins became visible on the surface of the left side of the chest. The glands in axilla, above the clavicle, and at nipple remained enlarged, though not increased in size. The integuments over the left side in front had a peculiar brawny feeling, not pitting on pressure. His temperature during the whole of his illness remained normal. His appetite was capricious, with a very remarkable craving for alcoholic stimulants.

Previous History.—F. N. had never been ill before the commencement of present illness, with the exception of slight attacks of dyspepsia. It was remarked during his illness that he had a very great craving for stimulants, and, I have been informed, that the craving had existed for at least three years. I have learned since his death that he would drink anything and everything that came within his reach—beer, brandy, and every description of wine that he could obtain.

Family History.—His father died young, from acute tubercular phthisis. His mother is alive in fair health, but delicate, and of a strumous diathesis. Three sisters and one brother alive, all delicate. The eldest girl decidedly strumous. Both parents have been temperate.

Post mortem Examination was made forty-eight hours after death. The body was much emaciated, the left side of the chest was considerably more prominent than the right, and the superficial veins of that side were dilated. There was considerable œdema of left arm and hand. On dissecting back the integuments nothing abnormal to right of sternum was observed, but to its left the tissues were found to be infiltrated by a whitish-yellow growth, so that the skin and muscles were firmly adherent to the sternum and costal cartilages. The morbid growth had invaded all the tissues, pushing its way through the intercostal spaces and replacing the muscular substance. On opening the chest the sternum and cartilages were found firmly adherent by the under surface to a large mass of the same growth. The whole anterior mediastinum was filled by a large tumour, which also ex-

tended somewhat to the left side of chest. The heart lay in a cavity in the right side of the tumour, the cavity containing several ounces of fluid. The heart itself was healthy with the exception of a small tumour projecting from the apex of left ventricle and invading its substance. This tumour had the same character as the larger mass. In the left pleural cavity was a large quantity of clear fluid. The left lung lay compressed against the spine, and was about three inches in length, of a grey colour, tough, and perfectly devoid of air. The right lung and pleura were healthy—there were no adhesions on either side. The tumour was firmly adherent to the under surface of the sternum, the costal cartilages, the diaphragm, and the tissues in front of the spine. It had invaded the fibrous structure of the pericardium, following the outlines of this structure, involving the large vessels, but invading neither lung. Taking the cavity in which the heart lay as the pericardium there was no evidence of recent inflammation on its serous surface. The liver was considerably enlarged, with patches of fatty degeneration. The other organs were not examined, the *post mortem* being limited by the wishes of the friends.

In the year 1869 I met with a case in a woman, aged 37, in which the pericardium appeared like a large solid growth. It was about 2 inches thick in the upper part, and gradually decreased towards the diaphragm, where it did not exceed $\frac{1}{8}$th of an inch. The morbid growth was soft and sarcomatous but not brain-like, nor did it yield a milky juice on pressure. The preparation was examined microscopically by the late Professor Hughes Bennett, who pronounced it to be a case of fibro-nucleated or cancroid growth, under which name it was described by me in the *Edinburgh Medical Journal*, March 1870. This tumour was also examined by Professor Turner, who came to a different conclusion as to its nature, and described and figured its microscopic structure in the 3d edition of Sir James Paget's *Lectures on Surgical Pathology*, which he was then engaged in editing, as an example of a lymphoid tumour in the mediastinum; for it consisted of a reticulated connective tissue, in the meshes of which crowds of lymphoid corpuscles were situated. He referred it, therefore, to the group of mediastinal tumours, the study of the true character of which had been, under the name of lymphosarcoma, so ably conducted by Professor Virchow.

I forwarded the tumour in the present case to Professor Turner,[1]

[1] Both this and the preceding lymphoid mediastinal tumour are preserved in the Anatomical Museum of the University of Edinburgh.

who has supplied me with the following notes on the structure of the morbid growth:—

"The tumour was 6 inches long by 4 inches wide. It was 2½ inches thick at its upper end, but not more than ½ inch where it was adherent to the diaphragm. Some of the left true ribs were imbedded in its anterior surface; superiorly it had surrounded the arch of the aorta, and the great vessels arising from it, the superior cava and innominate veins, the pulmonary artery and the trachea at its bifurcation; posteriorly it was incorporated with the fibrous bag of the pericardium. Its sides were smooth and covered by the pleural membranes. A furrow about 2 inches long extended longitudinally a little to the middle of the front of the tumour, as if to mark its division into two lobes. The tumour was not lobulated, but consisted of a compactly arranged toughish substance, very different in its consistence from an encephaloid tumour.

"When examined microscopically the framework of the tumour was seen to consist of a reticulum of delicate fibres, which crossed each other at various angles and sometimes possessed a nucleus-like nodule in their course; though one could not say that the network had the definite stellate cell-structure one sees in a lymphatic gland: occasionally fusiform cells were seen. The meshes of this network were occupied by very characteristic lymph corpuscles; so that the tumour formed a good example of the lymphoid group of tumours—a lympho-sarcoma. In addition to the network larger bands of distinct fibrous connective tissue traversed the tumour in various directions, which assisted in giving to it firmness and compactness.

"The question now arises, Where did the tumour originate? In its position it corresponded with that of a thymus gland, the relations of which had become somewhat extended. No thymus gland distinct from the tumour was to be seen in the specimen, though from the age of the patient, 6 years, that gland would not yet have atrophied and degenerated. I am of opinion, therefore, that the tumour is to be regarded as having originated in the thymus. The longitudinal furrow on its anterior surface, which marks the division of the tumour into a right and left portion, expresses, I believe, the original separation of the thymus into two lobes, which in the morbid condition had become almost completely fused together. In the course of its growth it had become so closely incorporated with the fibrous bag of the pericardium as to appear as if it had grown from it.

"That mediastinal tumours may arise in the thymus gland was suggested some years ago by Virchow and by Dr Church. In 1873 I examined, along with Dr Arthur Gamgee, a mediastinal tumour from a girl aged 5.[1] It closely resembled the example now described, but the division into two lobes was more distinct than in this specimen. Both Dr Gamgee and I were of opinion that it had had its origin from the thymus."

[1] Dr Gamgee has given a full account of this case in the *Edinburgh Medical Journal*, March 1873, p. 797.

INEQUALITY IN LENGTH OF THE LOWER LIMBS.

By J. G. GARSON, M.D. Ed., *Anat. Assist. Royal College of Surgeons of England*,

SINCE Dr Wright of Brooklyn and Dr Cox of New York first pointed out that the lower extremities are very often unsymmetrical in length, this subject has received considerable attention, especially from American surgeons. Dr Hamilton, whose name is well known in connection with fractures, at first doubted the accuracy of the statement, as to the limbs being *generally* of unequal length; but subsequent observations led him and several other surgeons to concur in the opinion. According to their observations the lower limbs of the same individual may vary as much as 300 mm., and the inequality seldom if ever affects the person's gait, being for the most part only observable when the limbs are compared with one another, or measured.

The subject has also received attention in this country, as in the *St Bartholomew's Reports* for 1878 Mr Callender has a paper upon it, in which he gives the measurements of the limbs of twenty-five persons. His experience is, however, contrary to that of American surgeons, as he only found two instances of a-symmetry in length in the twenty-five cases. Although not denying that it sometimes happens, he believes that much more extensive series of measurements are required, before it can be accepted that the limbs are, as a rule, of unequal length. Measurements on the limbs of the living or dead subject are necessarily more or less inaccurate, from the difficulty of obtaining definite points from which to measure, as well as from the measurements being usually made with tapes, which are liable to vary. This is not the case, however, with the bones, as they can be measured tolerably exactly, and the length of the limbs ascertained; but, strange to say, Dr J. C. Roberts of Philadelphia is the only one that, up to this time, as far as I know, has published any observations upon them. Dr Roberts, in a paper published in the *Philadelphia Medical Times* of the 3d August 1878, gives the measurements of eight skeletons. In them he found only one instance where the limbs were equal in length. General conclusions cannot,

however, be safely drawn from the measurements of so small a number of skeletons. There being at my disposal a considerable number of complete and well authenticated skeletons in the Museum of the Royal College of Surgeons of England, I thought it desirable to investigate the subject, in order to ascertain whether measurements on the skeleton bore out the observations of American surgeons on the living body, or the contrary, and to suppliment Dr Roberts' measurements. I have taken great pains to ascertain that the bones of each skeleton measured belonged to the same body, and rejected all those that were doubtful, or in which the bones were not perfectly normal and healthy. For assistance in this very important matter, and also for revising and correcting my measurements, I am much indebted to the kindness of Professor Flower, the Conservator of the Museum.

Although apparently easy, it is extremely difficult to measure bones exactly, and great care is required in the selection of a proper measuring apparatus. A uniform plan of measuring must also be adopted. Even after all possible care has been taken, bones will frequently give different measurements, especially if some time has elapsed since the previous measurements have been made. This is often due, as was pointed out by Professor Flower in his lectures last February,[1] to their varying in size according to their state of dryness or the reverse. Measurements of bones taken in winter will be found to differ considerably from those taken in summer, being usually larger in the former case, on account of there being more moisture in the atmosphere in winter than in summer. It is therefore necessary, when making comparative measurements, that the bones be as nearly as possible in the same condition, and in this particular instance, that the measurements of one limb be made at the same time as those of the other. The apparatus I have found most suitable is a flat board, about 80 cm. long by 10 cm. broad, to which a millimetre scale is attached, with two perpendicular uprights of the same breadth as the board, one of which is firmly fixed to the end where the scale begins, the other attached so as to slide backwards and forwards along the board; this latter upright should be made

[1] *British Medical Journal*, April 12, 1879, p. 540.

broader at the base than at the top, like a bisected triangle, with the flat surface opposite the other upright, the object of this being to prevent its being displaced backwards from the perpendicular when made to rest against the end of a bone. Altogether, the apparatus is similar to that used by a shoemaker for measuring the foot. The mode of measuring bones I have used, is the one now generally adopted in this country and on the Continent; and one which it is desirable for all who may make observations on this subject in future to adopt, as it would facilitate comparison between the measurements of different observers, as would also the uniform adoption of the metric system. It is done in the following manner:—The bone is laid horizontally upon the measuring apparatus, with its long axis, throughout its whole length, *parallel to the sides of the apparatus*, and with one end resting against the fixed upright, the other upright is slid against the other end, and then the length is read off the scale. In the case of the femur, where the internal condyle is longer than the external, only the former will touch the upright when the axis of the bone is in the proper position. In measuring the tibia I have included the spines and the maleolus. Special care is required to keep the axis of this bone in the right position, as it is liable to become displaced.

The following table contains the measurements of the skeletons of seventy persons, of various ages, from 12 years and upwards, of various sexes, and of various races of mankind. Owing to the English standard of measurement being inconvenient and troublesome to calculate compared to the metric system, I have adopted the latter.

On examining the table, it will be found that in seven instances only, or in 10 per cent., are the right and left limbs of equal length, and of these there are only two cases in which the femur and tibia of one side corresponds respectively to the femur and tibia of the other. In the remaining five cases, it is by compensation that the limbs are equal; *i.e.*, the tibia being shorter where the femur is longer, or *vice versa*. I may remark in passing, that the table illustrates very clearly the fact that to obtain accurate data from which to draw conclusions our measurements must be as extensive as possible, and that measurements of only

TABLE

Showing the Measurements of the Skeletons of Seventy Persons.

No.	Femur.		Tibia.		Difference in length of limb.		No.	Femur.		Tibia.		Difference in length of limb.	
	R.	L.	R.	L.	R.	L.		R.	L.	R.	L.	R.	L.
	mm.	mm.	mm.	mm.	mm.	mm.		mm.	mm.	mm.	mm.	mm.	mm.
1	422	424	355	355	...	2	36	464	470	398	400	...	8
2	440	440	391	390	1	...	37	397	398	323	324	...	2
3	441	437	358	361	1	...	38	447	449	379	378	...	1
4	417	426	348	346	...	7	39	439	444	378	377	...	4
5	395	397	344	348	...	6	40	375	378	297	296	...	2
6	409	411	347	346	...	1	41	459	455	402	402	4	...
7	367	370	300	299	...	2	42	410	407	346	346	3	...
8	448	447	380	379	2	...	43	432	434	377	381	...	6
9	425	432	342	347	...	12	44	442	439	366	364	5	...
10	425	428	362	362	...	3	45	385	389	324	324	...	4
11	445	443	360	360	2	...	46	364	364	316	314	2	...
12	462	467	389	390	...	6	47	377	379	335	333	equal	equal
13	380	378	338	338	2	...	48	393	391	336	331	7	...
14	356	363	308	312	...	11	49	428	425	378	381	equal	equal
15	419	420	347	347	...	1	50	466	473	397	397	...	7
16	437	439	360	350	8	...	51	447	449	370	370	...	2
17	482	482	382	389	...	7	52	443	449	373	369	...	2
18	625	642	544	538	...	11	53	359	360	304	306	...	3
19	506	507	397	390	6	...	54	404	402	357	355	4	...
20	385	381	300	300	4	...	55	450	453	381	380	...	2
21	479	483	377	378	...	5	56	395	399	314	310	equal	equal
22	447	445	351	352	1	...	57	378	384	312	315	...	9
23	455	452	372	380	...	5	58	380	381	317	316	equal	equal
24	588	589	484	482	1	...	59	392	392	330	330	do.	do.
25	491	500	412	416	...	13	60	413	416	344	348	...	7
26	305	304	241	244	...	2	61	457	457	367	370	...	3
27	477	480	381	387	...	9	62	441	433	354	355	7	...
28	400	397	329	327	5	...	63	492	494	415	412	1	...
29	358	358	303	305	...	2	64	422	422	345	344	1	...
30	393	394	345	342	2	...	65	473	474	417	417	...	1
31	397	400	345	344	...	2	66	469	468	413	410	4	...
32	459	455	303	302	5	...	67	444	447	369	370	...	4
33	390	393	328	328	...	3	68	513	511	427	429	equal	equal
34	382	382	321	319	2	...	69	436	436	368	368	do.	do.
35	384	380	323	323	4	...	70	486	491	411	411	...	5

a few cases are not reliable. It was not till I had measured 47 skeletons that I found one in which the limbs were equal. Had I taken only 50 skeletons, I should have stated the proportion of cases in which the limbs were symmetrical as 4 per cent. instead of 10 per cent. Again, between the 55th and 70th skeleton there are no less than five cases in which the limbs are symmetrical, which, as far as I can judge, would give too high a percentage. In 25 instances, or in 35·8 per cent., the right limb is longer than the left, the average preponderance of the former over the latter in these cases being 3·3 mm. In 38 instances, or in 54·3 per cent., the left is longer than the right, and its average preponderance over the right is 4·8 mm. The left limb, therefore, is not only more frequently longer than the right, but the difference between the limbs is greater on an average, when it is the longer than when the right is the longer, the greatest preponderance of the right limb being 8 mm., whereas that of the left is 13 mm. Over the whole 70 cases, the left limb is 1½ mm. longer than the right.

Analysing the differences still farther, we find that in 41 cases the left femur is longer than the right, in these its average preponderance is 3·8 mm.; in 20 cases the right is longer than the left, in these the average preponderance is 2·9 mm.; and in 9 cases the bones are equal. Again, in 24 cases the left tibia is longer than the right, the average preponderance being 3·0 mm.; in 29 cases the right is longer than the left, the average preponderance being 2·6 mm., and in 17 instances the bones are equal.

The inequalities in the length of the limbs do not, as far as my observations go, seem to be confined to any particular age, sex, or race, as I found that the limbs of young persons differed quite as much as those of many adults. There was the same variety in the limbs of females as males, and of Australians or Negroes as Europeans, &c.

Although much might be learned by comparing results, such as those just given, with the *actual* length of the limbs on living people, we are unable to do so, on account of having to measure the limbs of the latter from the anterior superior spine of the ilium neither the head of the femur nor the upper border of the trochanter major being available for this purpose, the former

from being so deeply situated, the latter from its margin being obscured by the insertions of muscles. In order to compare measurements of the extremities from the anterior superior spine of the ilium on the skeleton, with those on the living subject, I tried to measure the distance between the spine and the head of the femur where it rests against the upper border of the acetabulum in the erect posture of the body, on the skeletons, and add it to the length of the limb bones. Being, unfortunately, unable to find a definite point from which to make measurements on the spine, I had, after repeated trials, to abandon the attempt. Had I succeeded, I hoped to have been able to show whether the distance from the spine to the acetabula varied on the two sides of the body in the same way that the bones do, and whether there was any compensation in the pelvic bones, when one limb is longer than the other.

In conclusion, it will be seen that, if we disregard variations or compensation in the iliac bones, my results entirely agree with those obtained by the American observers on living persons. From those facts, and from the fact that other parts of the body are very frequently not symmetrically developed, I think it is extremely unlikely that the lower extremities are generally of the same length in living persons. This circumstance, though probably of comparatively small importance in the treatment of many cases of fractures, must always be kept in mind, as in some cases it may be of consequence. Its importance is, however, considerable in anthropology, and also in Medical Jurisprudence. Indeed, in the latter it has already played an important part in the decision of a case where the medical attendant was prosecuted for maltreatment.[1]

[1] *American Journal of Med. Science.*

A LARGE SUB-ARACHNOID CYST INVOLVING THE GREATER PART OF THE PARIETAL LOBE OF THE BRAIN. By D. J. CUNNINGHAM, M.D., *Senior Demonstrator of Anatomy, University of Edinburgh.*

DURING the early part of last winter session a male subject, remarkable for his huge frame, and the many points of pathological interest which his dissection revealed, was brought to the Anatomical Department of this University. When placed in the dissecting rooms he attracted universal attention, and many conjectures were hazarded as to the cause of his unusual bulk and peculiar appearance.

He was a man of a forbidding and low cast of features. His head and thorax were peculiarly large; his limbs were spare, though his hands and feet were enormous. On referring to the certificate of death, the only cause of death specified was *diabetes.*

The following are some of the measurements which were taken before the dissection was commenced:—

Height, 6 ft. ½ in.

Head.

(1)	Circumference immediately above the ears,	24¼ in.
(2)	Transverse arc (from one meatus to the other over vertex),	15½ „
(3)	Fronto-inial diameter,	8·3 „
(4)	Greatest breadth,	6·2 „
(5)	Radius to occipital protuberance,	4 „
(6)	Radius to vertex,	5·4 „
(7)	Frontal radius to frontal eminences,	5·1 „
(8)	Radius to supraciliary ridges,	4·6 „
(9)	From symphysis of lower jaw to vertex,	10·7 „
(10)	Width of face across zygomatics,	5·9 „

Chest.

Girth of chest 3 in. below the nipples,	46 in.
Girth of chest at the level of the nipples,	43 „

The chief points of interest in the dissection of this subject were:—

Circulatory and Respiratory Organs.—On removing the front part of the chest-wall the diaphragm was remarkable for its great

width. It did not reach higher than usual. The heart was large, but not out of proportion to the body. Clots were found in the right auricle and in the right ventricle. In the latter case it extended upwards into the pulmonary artery, and in both positions they were evidently the result of *post mortem* coagulation of the blood. The entire venous system was engorged with dark blood, and in many cases the veins were greatly dilated. The *vena cavà inferior* was expanded to about twice its usual calibre, and the *renal veins* were also remarkable for their great size. The veins of the legs and spermatic cords were varicose. The lungs showed no signs of disease.

Abdominal Organs.—The abdominal cavity presented an astonishing capacity, due to the great hypertrophy of all the organs which it contained. The enormous girth of the lower part of the chest, and the great expanse of the diaphragm, may be ascribed to the same cause.

The *liver* weighed 7¾ lbs., *i.e.*, more than twice its usual weight. It measured 17 inches from right to left, and 10 inches from its posterior to its anterior border. It was somewhat soft and flabby, but showed no signs of disease.

The *kidneys* were greatly hypertrophied. Indeed, they were each nearly three times their ordinary weight.

	Right Kidney.	*Left Kidney.*
Weight . . .	11 oz.	13½ oz.
Length . . .	6 in.	7 in.
Breadth . . .	3½ in.	4 in.

To all appearance they were quite healthy.

The *spleen* was also large. It weighed 14 oz.

The *stomach* and *intestines* had attained a wonderful capacity. The *stomach* was four or five times the size of an ordinary stomach. It had the usual pyriform shape, and when loosely distended with horse-hair, it had the following dimensions:—

(1) Along the greater curvative from the cardiac orifice to the pyloric constriction . .	37¼ inches.
(2) Along the lesser curvative from the cardiac orifice to the pyloric constriction . .	13 "
(3) Girth at cardiac orifice	29 "
(4) Girth at the pyloric orifice	7 "

In the Museum of the Edinburgh University there is a stomach of very extraordinary size. When compared, however, with the stomach in question, it sinks into insignificance. It is true that it has almost an equal length, but its expansion has been confined entirely to its long axis; its girth is little more than that of an ordinary stomach, and it is in this respect that the more recent specimen has the advantage of it.

The *small intestine,* when freed from its mesentery and inflated with air, measured 37 ft. 3 in. in length. Its calibre was correspondingly enlarged. The *large intestine* had a length of 11 ft. ½ in. The intestinal canal then measured 48 ft. from the pyloric orifice of the stomach to the anal orifice. In other words, it was little less than twice as long as it is in an ordinary male subject.

Osseous and Muscular Systems.—The bones were very large, and out of proportion to the muscular development of the subject. The enlargement of each bone was uniform and symmetrical. The following are the measurements of the lower jaw, which may be taken as a sample:—(1) From angle to symphysis, 5 in.; (2) From angle to tip of coronoid process, 4 in.

The bones of the skull were remarkably thick. The supraciliary ridges were very pronounced, and the frontal air sinuses of great extent. The pituitary body was hypertrophied, and the pituitary fossa had undergone a great expansion. The pressure exercised by the enlarging pituitary body had not only deepened and widened the fossa, but it had also rendered the dorsum sellæ vertical, and so thin that it was almost transparent. The fossa was 1 inch both in length and breadth, and ¾ of an inch in depth.

The muscles were poorly developed, and quite out of keeping with the huge frame upon which they had acted.

Nervous System.—The removal of the brain was by no means an easy undertaking, on account of the great thickness of the bones of the skull. When the calvaria was removed, a prominent fluctuating bulging of the dura mater over the parietal lobe of the right cerebral hemisphere was observed, and corresponding to this, a distinct depression on the inner surface of the skull-cap was visible. On running the knife along the dura mater, a large quantity of thin sero-sanguinolent fluid escaped, and on throwing the dura mater upwards, it was seen to flow

from a deep cavity in the right cerebral hemisphere. But as the dissection was proceeded with, another point of interest was discovered. The pituitary body was found to be enlarged to about four or five times its usual size. It was exceedingly soft and pulpy, and the greatest difficulty was experienced in raising it entire from the expanded pituitary fossa in which it rested.

The *Brain* weighed 50 oz. 6 drs. The right hemisphere of the cerebrum was considerably smaller, both in length and breadth, than the left hemisphere. The diminution in length was entirely confined to the parieto-occipital region. The frontal lobes were of equal length. On the other hand, the parietal lobe was half an inch, and the occipital lobe quarter of an inch shorter than the corresponding lobes of the left side. But the diminution in breadth of the right hemisphere was even more marked than the diminution in length, and it was apparent over the whole extent of the hemisphere. In the anterior part of the frontal lobe it was slight, but as the measurements were carried further back, the great disproportion between the breadth of the two hemispheres became very evident. The following are the vertical measurements :—

(1.) From the commencement of the fissure of Sylvius to the median longitudinal fissure :

Right side,	*Left side,*
$3\frac{1}{2}$ in.	$3\frac{3}{4}$ in.

(2.) From the fissure of Sylvius to the median longitudinal fissure at the inner end of the fissure of Rolando :

Right side,	*Left side,*
$3\frac{1}{8}$ in.	4 in.

(3.) From the lower margin of the hemisphere to the median longitudinal fissure at the parieto-occipital fissure :

Right side,	*Left side,*
$2\frac{1}{2}$ in.	$3\frac{1}{2}$ in.

This great disparity in size between the two hemispheres was in all probability due to a subsidence of the brain substance caused by the cyst excavation in the right parietal lobe. This cavity was large enough to hold a hen's egg. It had an ovoid form, its larger end being directed forward. Its long axis, which

hemisphere, measured 2½
inches; and its depth
arachnoid mater was
it in, whilst the pia
floor.

nded to the position
ascending parietal; (2)
the parietal eminence;
portion of the superior
therefore, was limited
y the parallel fissure,
behind it reached the

t (reduced to a little more
Rolando; PO, Parieto-occipital
convolution; PP, Postero-
ition.

of these four convolu-
sed in connection with
ution, below the level
y pressure to a slender
It was in relation to
the fissure of Rolando
upon both aspects by
ascending frontal convo-
Rolando could be clearly
expanded into a portion

about the size of a small bean—the only part of the ascending parietal convolution, below the level of the intra-parietal fissure, which had suffered little from the effects of the pressure.

The posterior part of the superior temporo-sphenoidal convolution and the angular convolution were present in connection with the lower wall of the cyst. They were quite as thin as the ascending parietal convolution, but, nevertheless, their identity and their continuity with the neighbouring convolutions could be established beyond the shadow of a doubt. The supra-marginal convolution was pressed upwards against the upper wall of the cyst, and was represented by a ragged and thin shred of nervous matter. The postero-parietal convolution had escaped the effects of the pressure, with the exception of its lowest fold, and this was considerably thinned. Indeed, it had a thickness not greater than paste-board. The floor of the cyst was smooth, white in comparison with the surface of the hemisphere and coated by pia-mater.

With these facts before us, there can be little difficulty in determining the true nature of this cyst. The fluid had evidently collected over the parietal lobe between the arachnoid mater and pia mater. It had forced its way between the convolutions, and by compression they had been reduced to these thin laminæ. To give a better idea of the extreme thinness of these convolutions, it may be mentioned that the entire thickness of a portion of the ascending parietal convolution was stained and mounted on a microscopic slide, and after it had been cleared up with turpentine its structure could readily be studied by transmitted light. Neither in this preparation nor in teased preparations of the thinned convolutions could nerve-fibres or nerve-cells be detected, but this does not disprove the fact of their being the convolutions referred to, seeing that a direct continuity of structure between them and the neighbouring convolutions could be readily traced. It proves, however, that, functionally, these convolutions were extinguished, and that all their essential elements had disappeared from the continued pressure to which they had been subjected.

In addition to the points noted above, the examination of this brain yielded other results of considerable interest. The *pituitary body* was greatly hypertrophied. It was fully as large

as a walnut and it projected upwards from the expanded pituitary fossa of the skull, so as to press upon the base of the brain. The space, bounded behind by the pons Varolii, in front by the frontal lobes, and laterally by the temporo-sphenoidal lobes, was hollowed out into a deep recess for its reception. The enlargement of this area was entirely confined to that part of it which is situated in front of the corpora albicantia. The crura cerebri and pons Varolii had successfully resisted the encroachment of the pituitary body in a backward direction. Owing to the deepening of the space, the corpora albicantia had been brought under the shelter of the pons, and thus they had escaped the effects of the pressure. The frontal lobes which limit the space in front had given way before the enlarging pituitary, and in consequence they had sustained a loss of substance.

In the floor of the space the optic commissure had been pressed forwards so as to lie altogether in front of the lamina cinerea. The tuber cinereum and the lamina cinerea were very much thinned, and the former was connected by a large infundibulum with the pituitary body. The optic-tracts and commissure, and the commencement of the nerves were rendered perfectly flat by the pressure. Upon each side, the optic tract was directly continuous with the tuber cinereum and lamina cinerea. The optic commissure, on the other hand, was continuous with the anterior part of the lamina cinerea, and together they formed a thin plate of nervous matter, which projected forwards so as to overlap the commencement of the median longitudinal fissure. On raising this lamina a circular aperture, which led into the third ventricle of the brain, was brought into view.

With regard to the *sympathetic nervous system* there was simply an enlargement of the splanchnic nerves. The left nerve showed this increase in size more than the nerve of the right side. This enlargement of the splanchnics must be associated with the hypertrophied abdominal viscera.

The interest of this case is much enhanced from our having succeeded in tracing the history for some time prior to death. For a period of two months he was in the Royal Infirmary of this city, under the care of Dr Claud Muirhead. Dr J. A. Sutherland, the resident physician, kindly supplied me with the

notes of the case as they are entered in the ward-book. These simply narrate the history of a case of strongly-pronounced *diabetes mellitus.* The patient was a fireman, aged 36. He passed 900 oz. of urine per diem when he first entered the Infirmary, but this was ultimately reduced to 300 oz. per diem. On applying to Dr Muirhead, I received a very interesting letter, of which the following is an extract:—

"The whole aspect and general configuration was so peculiar as at once to arrest the attention of any observant person. His frame was so huge, his movements so ungainly, his expression so unpleasing, the brow so overhanging, and the feet and hands so enormously large and flat as to suggest the idea to some in the ward of a resemblance to a gorilla, and by this epithet he was spoken of among the other patients. I was not aware of this till after he had left the hospital; and, on thinking of his appearance, I cannot say that I recognise the likeness. His voice was as remarkable as, and in unison with, his otherwise large development: it was strong, deep, and hoarse—in fact, the patients used to speak of the gorilla roaring when he called for anything he wanted.

"He had no symptom whatever of paralysis or paresis. So far from this he was in the habit, when he first came into hospital, of going to the kitchen to help the nurse to carry up the breakfast and dinner. He had no difficulty in carrying up a large tray containing twelve or thirteen bowls of porridge, and again in the afternoon fetching up two pitchers of soup. This, of course, he could never have done if there had been any impairment of motor or sensory power, more particularly as the ward of which he was an inmate is about the most distant one from the kitchen in the whole infirmary. Farther, this act of his, a purely voluntary one, showed that he was not insensible to kindness, and willing to oblige. But, while saying this much, I must allow that his expression indicated a low type of intellect—it was heavy, stupid, dull, utterly devoid of anything like active intelligence. He was quite uneducated; I believe that he could neither read nor write. He was easily irritated, and though sometimes he gave vent to this in a fit of passion, more commonly he exhibited it by hysterical weeping, and in this way his fits of anger invariably terminated.

"When he first entered the hospital he ate enormously, and was with difficulty satisfied, if, indeed, he ever was. Latterly he took more fluids than solid food, drinking largely of milk—often twenty pints or more of sweet or churned milk. At the same time he grew weaker, and frequently complained of severe pain in the left parietal region, which was at times so intense as to prevent him sleeping at all during the night. He generally made up for this want of rest by sleeping all day; and no doubt the pain would have been much more continuously present had it not been modified by the opium which, during the latter weeks of his residence in the Infirmary, was prescribed for him.

This case presents for our consideration two points of great interest and importance: (1) the great loss of brain substance in so important a region as the parietal lobe, and yet no symptoms during life to indicate the presence of such a lesion; (2) the enlargement of the pituitary gland in conjunction with the great bulk of the body.

According to Dr Ferrier, the motor area of the brain embraces the bases of the three frontal convolutions, the ascending frontal convolution, the ascending parietal convolution, and the postero-parietal convolution. But, further, he holds that the centres for the movements of the wrist and fingers reside in the *ascending parietal* convolution. In support of this view he quotes not only the result of his experiments upon apes, but also several cases in which paralysis, affecting more particularly the hand, was associated with a lesion invading this convolution. In his recent work entitled "*Localisation of Cerebral Disease*," p. 40, he says:—

> "Truly Samt has recorded a case in which a cyst was found on the cortex in the motor zone without motor disorder, but, as Charcot and Pitres remark, the actual destruction of the grey matter was not proved, since we know that tumours may press aside, without destroying the tissue on which they rest. Let the subject, however, be investigated anew with all the most modern methods, and with the utmost possible scrutiny. When a clear case of destructive lesion of the cortex in this region without motor paralysis is forthcoming, it will be time to cast aside the immense body of positive experimental and clinical evidence which we possess in favour of the thesis enunciated."

It seems to me that the case in question is of this nature. We have seen that the ascending parietal convolution, below the level of the intra-parietal fissure, was so thin that it could be examined under the microscope by transmitted light, and, further, that all its essential elements—its nerve-fibres and nerve-cells had disappeared from the effects of pressure. Notwithstanding this lesion of the so-called motor area, we have the direct testimony of Dr Muirhead, who attended the patient during life, that there were no signs of paralysis. It is true that the entire convolution was not destroyed, that a portion was left both at the upper and lower ends. Together, however, these portions would not make up so much as one-third of the entire original convolution. It can hardly be supposed that this could have discharged the function of the whole convolution.

The angular, supra-marginal, and the posterior part of the superior temporo-sphenoidal convolutions were also destroyed. These convolutions belong to a region in which Ferrier considers that the centres of special sense reside. He believes that the angular gyrus has to do with the sense of sight, and the superior temporo-sphenoidal with hearing. In this case both sight and hearing were unimpaired, notwithstanding the fact that the optic-tracts, commissure, and nerves were rendered perfectly flat by pressure. Ferrier states, however, that these centres may be destroyed in one hemisphere without permanently extinguishing the senses with which they are connected.

In 1877, Dr Henri Henrot (*Union Medicale et Scientifique du Nord-Est*), published a very peculiar case of general progressive hypertrophy. The interest of this case was centred in the fact that there was a great enlargement of the pituitary and pineal bodies, and a great hypertrophy of the sympathetic nervous system. The pituitary body was as large as a small hen's egg.[1]

In addition to the diabetes mellitus, I think there can be little doubt that the subject, whose case has been narrated above, had also suffered from general progressive hypertrophy; or in other words, that he had been the victim of two conflicting diseases—the one which wasted, and the other which led to an enlargement of his frame, and that it was owing to the diabetes that the hypertrophy had been kept so far in check. We may consider, then, this to be the second case in which general progressive hypertrophy has been associated with enlargement of the pituitary body.

[1] For an abstract of this paper see "Notes on Hypertrophy of the Sympathetic System," vol. xii. of this *Journal*.

ON THE PROCESS OF HEALING. By D. J. HAMILTON, M.B., F.R.C.S.E., L.R.C.P.E., *Demonstrator of Morbid Anatomy, Edinburgh University; Pathologist to the Edinburgh Royal Infirmary.* (Plate XXIV.)[1]

IN making the "Process of Healing" a subject of special investigation, we cannot but feel that an apology is necessary for having ventured on a line of research which many will consider has already been, so to speak, "worked threadbare" in the hands of some of our greatest surgeons and surgical pathologists. When, however, we found, some time since, in looking into the literature of the subject, that in nearly all the text-books on surgery and surgical pathology, five methods of healing are described, we became convinced that either the ordinary laws of histogenesis were at fault when applied to wounds, or that this statement was entirely unfounded on fact. It was, therefore, with the purpose of clearing up this apparent anomaly that we were led to enter upon the present inquiry, and we hope that we will not be considered paradoxical in announcing, as the text of our observations, that we believe there is only *one* method of healing, and that there is no such thing as "healing by granulation." It will be the object of what follows to show some of the evidence by which we have been led to these conclusions.

It is a well known fact, if the cut surfaces of a recently incised soft tissue be examined in about twelve hours after the incision has been made, as, for instance, after the amputation of a limb, that they have a peculiarly glossy appearance, due to the presence of a slightly viscid fluid which has been effused after the bleeding has ceased. It is usually blood-stained, and can be poured out in such quantity that the dressings may be soaked with it. There is not necessarily any blood-clot to be seen on the exposed tissues, unless such as may accidentally have been retained within their recesses. If this wound be again examined in from twenty-four to thirty-six hours after its infliction, it will be perceived that the glossy appearance is gone, and that the surface is covered with a greyish-coloured deposit. And

[1] Read before the Edinburgh Medico-Chirurgical Society, May 6, 1879.

now, if the two cut surfaces be placed in contact, and if external sources of irritation be removed, they are found in about forty-eight hours to be adhering, and in from three weeks to a month there is a permanent fibrous bond of union between them.

How is this brought about, and what are the successive stages in the process?

Let us first examine what the material is which produces the glazing of the cut surfaces. In figure 1 there is represented the edge of a flap twenty-four hours after the amputation of a limb, where the parts were quite free from any irritation further than that caused by the operation. Some of the adipose tissue of the part is seen at one side of the preparation (A), while the line at B represents where the tissue ends and the exudation on the surface begins. All the material beyond B has been exuded on the surface, and is that which causes the glazing. On examining the neighbouring adipose tissue it will be observed that the fibrous stroma lying between the fat cells contains more cellular structures than it should normally, and on looking at the exudation on the cut surface it is found to have the following composition: It consists of somewhat ill-shapen, small round cells lying in a granular basis substance. The cells are not exactly like blood leucocytes, they more resemble the incompletely developed round cells, that are found as constituents of normal lymph when taken from a lymphatic vessel. They form a layer more or less thick over all the cut surface, and those which are furthest away from the side of the tissue, that is those which have been first poured out, are always less completely developed than those more recently effused. The material in which they lie has none of the appearances presented by fibrin. It is granular, and has not the fibrillar structure of a fibrinous mass. We have found this to be the case so constantly that we are compelled to believe that this is not a "fibrinous lymph," and that the material which is first effused possesses no fibrin in its composition, or, at any rate, that under ordinary circumstances it is not formed on the cut surface of a tissue when free from inflammatory excitement. The only instance in which we have seen any fibrin in such a wound was where a little blood-clot had been accidentally retained, but this is so rarely seen that we believe there is no necessity for

its formation in the primary union of the cut surfaces, and that it is usually absent. What, then, is the substance first effused on the cut surface?

When a part is incised we know that the blood-vessels bleed, and we accordingly tie them or apply other means to cause the arrest of the hæmorrhage. We little think, however, that there is another set of vessels—the lymphatic—which must also be cut across, and which must continue to pour out their contents long after the hæmorrhage has ceased, owing partly to no artificial means being applied to close them, and partly to the feeble power of coagulation which lymph taken from a peripheral part possesses. Every interfibrillar space is a lymph space, and when a part is incised it is naturally to be expected that the discharge of lymph from these and from the larger lymphatic vessels would be very great. The lymph circulating in the lymphatic vessels contains leucocytes; and, in other respects, much resembles the liquor sanguinis, with this exception, that it has a much feebler power of coagulation. The explanation, therefore, of the glazed surface is not very far to seek—it is caused simply by the lymph which has escaped from the cut lymphatic vessels. When the parts are brought into accurate contact, the flow of this fluid is lessened in amount; it becomes more condensed by evaporation, and the albumen contained in it undergoes precipitation. The lymph corpuscles consequently become relatively more abundant, and they are naturally arrested on the surface as it becomes more viscid. It is thus, that the appearance seen in figure 1 is produced, and it is this material which serves as the primary bond of union between the divided parts. The adhesion of the surface is at first brought about merely mechanically by the intervention of this highly albuminous and viscid fluid, and not only does this serve a merely mechanical purpose at first, but we hope to show that its function throughout is merely mechanical and temporary, and that it takes no part in the construction of the permanent cicatrix. Very soon after it is effused its corpuscles become granular and fatty; they are destroyed, and they, along with the albuminous precipitate in which they lie, are in a short time absorbed. The materials for the formation of the cicatrix are derived from an entirely different source.

We must next take into consideration the condition of the surrounding parts in a wounded tissue which is free from any irritation further than that caused by the passage of the knife through it; let us suppose in a wound treated on antiseptic principles. There is no animal so well fitted as man for the study of the process. In all the lower animals the difficulty of keeping the wound free from irritation, putrefactive or otherwise, always introduces an element of fallacy into the observations, which can be prevented by the careful dressing of a wound in the human subject, and, for this reason, we have taken special care to select cases which were known to have been free from all inflammatory excitement, and in which death resulted from accidental or extraneous circumstances.

It is often said that the blood-vessels in a wounded part exude leucocytes which subsequently organise and form the cicatrix, that they take part in the construction of what is loosely termed a fibrinous lymph, out of which the cicatrix in some way grows. No one has ever seen them form fibrous tissue, but it is generally supposed that they are capable of such a high organisation. In wounds, however, which are free from putrefactive or other extreme irritation there is not the slightest evidence to show that they pass out from the vessels at all, or, at any rate, in greater numbers than in a healthy part, provided that all vascular distension has been prevented by accurately applied pressure. The terminations of the arteries in such a wound are plugged with fibrin as far as the extreme limits in which the active reparative changes are proceeding, so that no blood could have been circulating within them. There is no appearance of the crowding of leucocytes around, in the walls of and within the small blood-vessels, such as one sees in an inflamed part. The vessels, with the exception of their cut extremities being plugged, are not in any marked respect different from those in the healthy part, up till within a period of several days. In from thirty-six to forty-eight hours after the incision has been made, however, the edges of the wound, for a distance of from half a line to a line, are infiltrated with comparatively large, round, and oval-shaped cells, having many nuclei, and quite different from the somewhat irregularly round and shrivelled cells that one finds in the lymphatic fluid glazing the surface. What are these cells, and

why is it, even in wounds that are free from untoward irritation and vascular distension, that they are always present in such large numbers?

In figure 2 is shown a small piece of fascia from the edge of a wound which was perfectly antiseptic and free from any source of irritation, further than that caused in the mechanical division of the parts. A fascia is composed, in great part, of dense bundles of white fibrous tissue, upon which there lie, in the normal state, large, flat, usually oval-shaped cells, which can be seen comparatively easily in the healthy state, but which require special methods of preparation to bring them prominently into view. It is mainly to Ranvier that we are indebted for what we know of their nature, and of their relationship to the bundle of white fibres on which they lie. They are what were formerly termed "connective tissue corpuscles," but at the present time sometimes go by the name of endothelia. It will be understood from this what we mean when we state that in twenty-four hours after a knife has been passed through a tissue, even although there be none of the symptoms usually designated as inflammatory, the nuclei of these cells become unnaturally prominent; they swell, rise from the surface of the fibrous bundle, elongate, and finally divide into two, each divided part in turn undergoing a similar transformation (fig. 2). It is difficult to form any conception of the enormous extent of this division unless by seeing it some hours after an incision has been made through a fibrous texture. The drawing we give (fig. 2.) represents a small portion of such, and it will be seen how every nucleus overlying a fibrous bundle is undergoing active proliferation. Nuclei develope with great rapidity within the proliferated parts, so that in a short time the whole neighbourhood of a fibrous texture becomes infiltrated with large germinating cells. These wander through the connective tissue spaces towards the cut surface, and they then come to infiltrate its edges. It is they which are found in a few days on the surface, and as they increase in numbers they begin to construct a layer more or less dense. This very soon displaces the deposit of lymph, which we saw was at first effused, and which formed the temporary means of adhesion, and forces it further inwards towards the centre of the wound; while very soon after this takes place

the cells contained in the lymph are noticed to undergo disintegration and to be absorbed.

The cells, however, which are contained in this new layer, and which are derived from the connective tissue elements, now begin to alter in shape; they elongate and become spindle-shaped, and cease to proliferate so actively. The area from which they are derived is very small, much smaller than would be expected. We have measured it in several instances, and find it to be not more than two lines at the utmost, while beyond this the tissue has a perfectly natural appearance. The materials for the repair of a breach of continuity in a tissue are, therefore, derived from its immediate vicinity, and evidently from those tissues alone which have come under the immediate action of the knife.

We have, then, got so far in the study of the repair of the wound; the lymph has been poured out from the lympathic vessels, it has served to unite the cut surfaces mechanically, it has degenerated, and its place is now taken by a layer of cells on each side of the wound, derived from the proliferation of the connective tissue corpuscles in the neighbourhood.

How, then, is the fibrous tissue of the cicatrix produced?

It is said by many that it is elaborated from the fibrin lying in the wound. By some obscure process they would have us believe that this purely chemical substance is capable of developing the fibrous tissue of the cicatrix. We could as well imagine, if white of egg were introduced into a wound, that it would develope fibrous tissue! We have, moreover, seen that from the commencement of the process there is no fibrin effused between the two cut surfaces, out of which the fibrous tissue might be developed, and by the time that fibrous organisation has commenced even the lymph which was at first present has degenerated and disappeared. We fear that this very crude theory respecting the powers of organisation possessed by fibrin must be abandoned. We have given great attention to the process of fibrous tissue formation in the adult, in many different parts, under the most varying circumstances, and from what we have seen we believe that the laws which guide it are constant, and that the following represents a summary of the means by which it is accomplished. We would have it distinctly understood, however, that this is the process in the adult; we are not prepared to say that

it is the same in the embryo in all particulars. All newly-formed fibrous tissue in the adult arises from previously existing protoplasmic structures derived from the mesoblast. Division and multiplication of these, such as we have described, are the first phenomena noticed; elongation of the divided portions, and conversion into spindle-shaped cells follows, and then the periplast of the spindle cell by further elongating, and apparently by undergoing some peculiar albuminoid chemical change, becomes converted into a fibrilla of fibrous tissue, while the nucleus remains *in situ* as the connective tissue corpuscle. This can be seen proceeding in the layer of elements derived from the neighbouring fibrous tissue on each side of the wound, shortly after they have been formed, and it is undoubtedly by this means that the fibrous part of the cicatrix is produced.

A very favourable situation for seeing the whole process is in the pericardium in acute fibrinous pericarditis. The two surfaces of the pericardium are, at first, united merely by fibrinous effusion, which is sufficiently plastic in character to maintain the union of the two sides of the pericardial sac, until the fibrous cicatrix is developed. On each side, however, underneath the fibrin there is a layer of cells derived from the connective tissue of the peri- and epi-cardia, which gradually encroaches on the fibrinous effusion as it degenerates and becomes absorbed, and in which the organisation into fibrous tissue may be studied with great advantage. The two layers of connective tissue elements finally meet and blend together as the primary fibrinous exudation is removed, and they then constitute the permanent fibrous bond of union. Shortly after the fibrinous layer is effused, its leucocytes are seen to undergo fatty degeneration, and they take no further part in the construction of the cicatrix. It is therefore evident that even in this, which is an inflammatory affection, the true fibrous tissue of the cicatrix is derived from pre-existing fibrous tissue, and that the effusion of fibrinous lymph is to be looked upon more as an accident than as subserving any truly histogenetic purpose. The means by which the obliteration of a cavity such as the pericardium is brought about are accordingly similar to those which are instrumental in uniting a wounded soft part.

It might be said, however: "Does not a blood-clot organise?

Does it not become vascular? Will it not fill up a gap in a tissue, and if so, is its fibrin not converted into fibrous tissue?" Our answer to these questions is that we believe that it never does organise, but that there is a fallacy connected with this which is extremely deceptive. If it be true that blood-clot organises, then why does organisation not take place in a bruise of a subcutaneous tissue where it is effused in greater or less quantity? Why does it not organise, for instance, when effused in a dislocation of the head of the humerus? It is a matter of every-day experience, on the contrary, that if the skin remains unbroken, it is absorbed and leaves no evidence of its presence. If it be effused on an abraded surface it may become vascular, and it is this mainly which has led to the theory of its capability of further organisation. John Hunter notices this vascularisation of blood-clot on a free surface, and describes the process as healing by blood-clot, and Mr Lister has shown that this constantly occurs where the wound is kept free from irritation. Mr Chiene has given a most graphic account of the process in a case where a blood-clot apparently served to fill up a gap in a tissue by becoming vascular and organised. But there is nothing remarkable in this, and we hope to show that the fact of its becoming vascular is no evidence of a blood-clot being a living tissue capable of higher organisation. Mr Lister himself has shown that the *carbolised putty* formerly used in antiseptic dressing will, in a similar manner, become vascular under the same circumstances, and will bleed when pricked. This is quite in keeping with what we shall endeavour to prove in the sequel in regard to the formation of granulations on an abraded surface, and is easily explained on that basis, so that the fact of the blood-clot on an abraded surface becoming vascular is no proof of its being a tissue capable of higher organisation.

The process of healing of a solution of continuity in a tissue as we have described it, is what is witnessed when the parts are free from all irritation other than that excited by its division, and at the end of a month all that is seen is a depressed epithelial surface and a small scar about a quarter of a line broad. In some cases the latter is even absent, no trace of the incision being visible in the part. The surrounding parts do not

seem to have undergone the slightest alteration, the two epithelial surfaces have united, and the bundles of newly-formed fibrous tissue in the cicatrix simply appear to interlace with those in the natural tissues around, and thus bring them in contact. The repair has been brought about under such circumstances by the least expenditure of material possible, and the cicatrix left is only sufficient to maintain the parts in contact. What happens, however, if the wounded parts become irritated from any cause, and if what we understand as inflammatory symptoms are set up? We know that the vessels of the part dilate, a phenomenon described by Billroth as "fluxion," and evidently considered by him to be part of the natural process of healing. This is never seen where the part is free from stimulation, and where accurate pressure has been applied; hence the pallor which wounds treated on antiseptic principles present. When this "fluxion" does occur, however, the vessels become engorged with blood, and now it is that distinct evidence of the passage of leucocytes through their walls is obtained. They are seen adhering to the inner coat, lying in the wall, and in large numbers outside the vessel, from which situations they soon wander into the cavity of the wound. It is a subject of the greatest interest and importance to make out definitely what then becomes of them. So many doctrines have been advanced about their organisation, with the barest evidence to support them, that one feels inclined to pause before making any rash statement on the subject. We are convinced from what we have seen that they do not organise, but, on the contrary, that they act as foreign bodies, and must be got rid of before organisation can proceed. They may be removed in various ways, but, so long as they continue to accumulate in the part, organisation is hindered. The commonest method of their removal is by their becoming fatty, dying, and being thrown out as pus. They form an abscess, or they constitute the cells of a purulent discharge. Some of them are probably reabsorbed by the blood-vessels, and others enter the lymphatics, and are removed in this way. That they organise, even after acute inflammatory symptoms are past, into fibrous tissue, there is, we believe, no evidence to prove. Their natural function while in the blood is, in all probability, to form coloured blood corpuscles, and when they are effused into a cavity in

which they cannot reach their ultimate destiny they die and are rejected.

The method, therefore, by which the repair of a part is brought about, if kept free from undue irritation, is simply that each component of the cicatrix is reproduced from a pre-existing tissue of the same nature. The epithelium generates epithelium, and the white fibrous tissue is reproduced from the nuclei lying upon fibrous tissue already present. Yellow elastic fibres, which may be regarded as dead products, or what Beale calls formed tissue elements, having no nuclei whence a new tissue could be developed, are never reproduced in the cicatrix. This is what is known as healing by the first intention, and we shall now proceed to examine the conditions of healing by what is called the second intention, although, as we hope to prove, there is no essential difference between the two, the process by which the cicatrix is formed being alike in both.

When an open wound is left exposed, and no accurate pressure is applied to its surface, it begins to granulate; vascular tufts form upon it, and from this granulating surface a discharge more or less purulent is given off. As the wound heals it contracts on all sides, and there is formed at the edge a bluish pink pellicle, easily detached, which represents the young epithelium covering the abraded surface. The part of the wound outside of this is almost colourless, and corresponds to the part which has already healed. We do not remember having seen any explanation of this sequence of events; no one, so far as we understand, has ever given a rational explanation of why an abraded surface commences to granulate, and why a granulating surface always is an abraded surface. It is said that the production of granulations is an effort of nature towards organisation, a means of supplying nutritive material to a part in a state of organisation; and it is generally considered that the blood-vessels of the granulating surface are newly-formed in the part, and assist in the organising process. We beg to differ from these generally accepted views, and trust to demonstrate that granulations do not illustrate the "vis medicatrix naturæ," but that they are mere mechanical productions dependent for their construction on well-known physical laws; and further, that instead of aiding in the process of organisation, they are one of the great hindrances

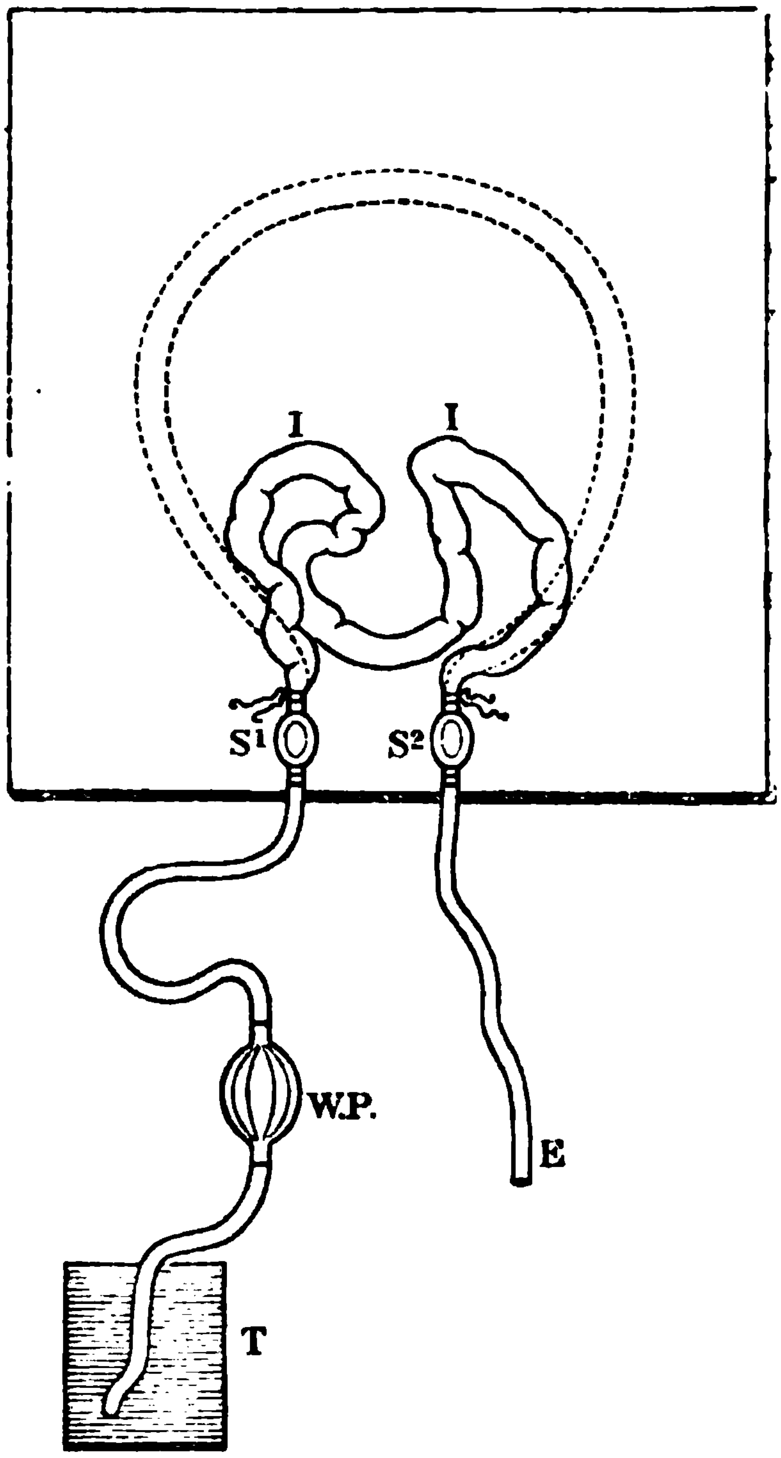
in effecting this desirable result. We have represented a portion of a granulation taken from a typically healthy healing wound of the leg in fig. 3. As will be seen, it is made up of a loop of a capillary vessel, taking its origin from a larger trunk, and, in this case, making its way back to join the same trunk from which it was given off, although this is not always the case, the distal end frequently ending in a vein. Both methods of termination are to be met with, the latter being the commoner of the two arrangements. The convexity of the capillary loop is always at a point opposite to the direction of the blood-stream in the branch from which it is given off, and a continuous horizontal section through a granulating surface shows that the capillary loops arise in bunches, each little bunch communicating with an artery at a deeper level. The vessels of the granulations resemble capillaries in structure, and are usually wider in calibre where they arch round, than where given off from the arterial trunk. They usually contain a considerable number of coloured blood-corpuscles, and always a great many leucocytes. Around the capillary loop large numbers of leucocytes are to be seen (fig. 3) lying in a delicate mesh-work of white fibrous tissue, with occasionally a few yellow elastic fibres. The surface of the granulation seems to derive its outline and smooth appearance from some of these leucocytes being flattened, and from the occasional presence of some stray fibres of white fibrous tissue. The granulating surface in a typically healing wound is usually a little higher than the epithelial edge, but varying degrees of elevation and depression are met with according to the loss of tissue which has taken place. One thing is constant—wounds never "heal up," as the vulgar phrase expresses it, but, on the contrary, are much more liable to "heal down," the resulting cicatrix being either on the same level or deeper than the surrounding parts.

Such being the structure of a granulation, we are next met with the somewhat puzzling question as to their mode of origin. Why do vessels take this convex shape, and why is an abraded surface necessary before the granulations arise? If the vessels are newly formed in the part, why do they always assume the character of an arch? They do not simply ramify in the part, but, on the contrary, stand out at right angles to it, and, at first

sight, this seems to be a somewhat unaccountable phenomenon. Let us suppose, for the sake of illustration, that a limb has been amputated, and that the flaps have been left free to granulate. The flaps have not been placed in juxtaposition, and no pressure has been applied to the cut surfaces. The arteries are tied, the tourniquet is removed, and the circulation returns to the part. The heart's impulse and arterial tension are the same as before, or, if the blood of the limb has been pressed out from it before operation, the tension may actually be higher than it was at first. The blood which formerly circulated through the main artery meets with complete resistance at the ligatured end, and, consequently, the energy formerly employed in driving it onwards will now be diverted into the branches which come off from it; that is to say, into the capillaries ramifying upon the cut surfaces and their surroundings. The same thing happens from simple ligation in the continuity of the artery without amputation, as evinced in the blush of redness observed in what is described as the "setting up of the anastomotic circulation." The enlargement which the anastomotic vessels undergo is due simply to the blood-stream which formerly passed through the main trunk being diverted into smaller channels, and, of course, exerting increased pressure upon their walls. The propelling apparatus has not as yet accommodated itself to the altered circumstances, and, consequently, becomes an agent for good or evil according to the purpose for which it is utilised. In the case of ligature in the continuity of a vessel, we know that as the capillary and other vessels enlarge, the circulation is restored to the part; but in the case of an amputation, where the part beyond the ligature has been removed, what will happen to the capillary vessels attached to the ligatured extremity of the artery? The first part of the answer to this is easy enough: they will dilate. Is this the whole change that they will undergo, or will they become still further altered?

In order to see what would further happen to them we devised the following experiment, illustrated in the accompanying figure. Let S^1 S^2 represent two stop-cocks of equal calibre, and let them be attached to each end of a coil of intestine (I), and further, let the stop-cock S^1 be attached to a bivalve pump (W.P.), from which a stream of water may be rhythmically driven

through S^1 into the coil of intestine and make its issue through the stop-cock S^2. We suppose in this scheme that the pump and attached tube represent the heart and arteries, and the intestine I represents the attached system of capillaries, while the exit stop-cock and attached pipe may either represent the vein in communication with the artery, or it may perhaps be more convenient to let it represent the continuity of the artery, the capillaries in either case being supposed to be intermediate. The intestine, it will be observed, is thrown into folds at present, and now let water be driven by means of the bivalve pump through the intestine, the stop-cock at the aperture of entrance being at first of the same calibre as that at the aperture of exit. Under these circumstances, even when exerting as much pressure with the pump as possible, it is found impossible to unfold the coils of intestine. Let the aperture of exit however be made a little smaller than that of entrance—a small difference in size is sufficient—and at the same time continue the same amount of pressure as formerly or even less, and now an entirely different result is noticed. In the first place, the intestine becomes distended, and then it gradually unfolds itself from the coils into which it was thrown, in the direction of the dotted lines in the scheme, and assumes the appearance of an arch, with its convexity furthest away from the direction in which the pressure is exerted. A comparatively small amount of force exerted on



the bivalve pump is sufficient to effect this, and the unfolding occurs as soon as the piece of intestine is filled. The explanation of this phenomenon apparently is that when the aperture of exit is rendered smaller than that of entrance, a certain amount of resistance is experienced in the out-flow of the water, and as the intestine becomes distended it tends to straighten itself. Both ends are, however, fixed, and the effect of this is that the intestine is shot out in a loop with its convexity opposed to the direction of the stream entering it. Were the coils of intestine held down in their places by any means, then no unfolding would occur. It is when there is no opposition to their unfolding that the formation of an arch occurs, for, were they fixed, then all that could possibly happen would be distension, with possibly the throwing of them into convolutions.

If we now use this experiment to explain the formation of the capillary loops in granulations, we shall see that the conditions are identical. In the case that we have supposed (p. 529), the limb has been amputated and the cut surfaces exposed without any pressure being applied to them. Ramifying on these cut surfaces there are numberless loops of capillary vessels running in all directions, some of them cut through and others merely laid bare. When the main artery or arteries are tied the energy formerly expended in driving the blood stream through them is directed into these capillary paths; there is nothing to restrain them, they are not compressed by any agent such as the skin, and, as a consequence, they first become distended and are then thrown out into convex loops. The process can be seen in from two to three days after the wound has been inflicted, the vessels at the edge of the wound becoming distended, pushed forward, and finally assuming the appearance of the vascular tufts which we call granulations. As the vessels are pushed forwards in this way, they bear along with them certain of the structures on the cut surface. Portions of muscle, fascia, and other structures which have been cut through are carried forward upon the distended vessels and are then thrown off; and this constitutes what is usually termed the "cleaning of the wound." The portions of tissue thus detached are dead, and are merely removed by this mechanical agency. Some of the living fibrous tissue, however, lying

around the capillary loops and small arteries, is also carried forwards, and frequently a few elastic fibres are displaced in the same way, and this accounts for the fibrous mesh-work which is usually seen around the vessels of granulatious (fig. 3 *b*). We would, therefore, look upon the granulation vessels as in great part merely the result of over distension and displacement of the capillaries naturally found in the part, and not as vessels which have been freshly developed. No doubt hernial protrusions from them may occur at a later period; but we are convinced that they, in the first instance, are merely the vessels of the cut surface which are displaced from it by the altered conditions of blood-pressure and the loss of the restraint which the skin when entire exerts upon them. The depth from which these vessels spring varies, but is usually from one to two lines. Below this, the fibrous textures which surround the vessels keep them in their places, and there is not the same tendency to displacement.

The superficial capillary vessels on the exposed surface being now thrown out into loops, the next changes observed become inevitable. These capillaries are distended; their walls are thin; there is increased pressure brought to bear upon their contents; and they have assumed the shape of loops. These, we know, are exactly the circumstances which favour the escape of leucocytes, and, accordingly, we find that, whenever these conditions are fulfilled, leucocytes exude and form the granulation cells. They accumulate around the granulation vessels, and when their numbers become excessive they are thrown off as pus corpuscles. The fluid part of the blood also exudes from the same cause, and, mixing with the ejected leucocytes, constitutes the "liquor puris." The well-known fact, that the discharge of true pus *follows* the appearance of granulations, and does not *precede* it, supports what we have observed in the process.

It might be asked, however, why is it, if these statements regarding the formation of the blood-vessels be correct, that the whole surface of the body is not a granulating surface? We reply, that it would be so were it not for the restraining function of the skin and mucous membranes. We think that this, one of the most important functions of the skin, has been entirely neglected. There is a constant pumping action going on in the heart, acting

on the peripheral capillaries, and tending to force them outwards and to cause their displacement; and yet we never think it necessary that there should be any restraining influence to hold them in their places. Remove the skin from a part of the body, as in a burn, and what happens? The whole denuded surface is converted into a mass of granulations, and remains in this condition so long as means, natural or artificial, are not adopted to prevent it. None of the free surfaces of the body are denuded surfaces. All have a more or less strong protective covering, which restrains the blood-vessels in exacerbations of blood-pressure; and, when we look at a granulating surface in a denuded part, we are simply observing what would occur generally over the whole periphery were the restraining influences of the skin and mucous membranes not sufficient to counterbalance the blood pressure exerted upon the superficial capillaries. We have shown ("*Practitioner*," 1879) that, in acute inflammation of the bronchi, so long as the elastic basement membrane, which we have there described, remains entire, no granulating surface is ever produced. This elastic basement membrane is a very tough structure, and undoubtedly one of its chief functions is that of restraining the vascular net-work which underlies it. It is the same, we feel convinced, on all free surfaces; there is always some such provision for preventing capillary displacement.

In confirmation of these statements, we may examine what will occur if the two flaps of the wound in the operation we have presupposed (p. 529) are brought into mutual contact, and if accurate pressure be applied so that the denuded surfaces are forcibly compressed, and at the same time are free from inflammatory excitement. In such a case the blood-vessels become very slightly dilated, and the vessels which pass into the young cicatrix are few in number. Billroth gives some figures in his work on *Surgical Pathology* which are supposed to represent the condition of the vessels in the sides of a wound healing by the first intention. We must say that we have never seen such appearances in wounds free from inflammatory excitement, and we cannot but look upon these drawings as mere diagrammatic representations of supposed conditions which in reality do not exist. In wounds healing typically by the first intention, as in those seen in cases treated antiseptically in the

human subject, and where the two surfaces have been brought into accurate contact, there is no such vascular dilatation, the universal pallor which the wound presents to the naked eye bearing this out. The reason of this is apparent. The two denuded surfaces have been brought into accurate contact, they exert a mutual pressure, and, restraining the capillary vessels, prevent the displacement which otherwise would occur. The absence of any irritation which might distend the vessels and increase the tension of the blood within them is also, of course, specially favourable to the prevention of this vascular displacement. A few of them are thrown out into the cicatrix, but these are merely sufficient to nourish it; there is nothing like a granulating surface produced. Separate the two surfaces before the union is complete, remove the accurate pressure which they have mutually exerted, and then granulation will commence.

Suppose, by way of experiment, we were to increase the blood pressure in the vessels of a granulating surface, we would, *a priori*, expect that they would become distended and larger. We have an actual experience that this is so in the every-day observation of ulcers of the leg. So long as the patient walks about, or leaves the leg hanging down, the granulations will become flabby, they will grow in size and number, and the discharge from them will be increased. What treatment does the surgeon naturally adopt? The limb is raised, and a bandage is accurately applied to keep up a continuous equable pressure. These mechanical measures are employed to supply the defect in the cutaneous covering.

The same principles hold good in the formation of all granulating surfaces, whether produced, as we have supposed, in the flaps of a clean cut wound, or as a result of a laceration. In a laceration, the skin or other restraining covering is torn, certain of the blood-vessels are destroyed or plugged, and, consequently, undue pressure is exerted on the surrounding capillaries. These are the circumstances most favourable to the sprouting upwards and displacement of the capillaries; and the cause of the granulations consequently becomes evident. In a granulating surface resulting from an ulceration, we have essentially the same conditions. The vessels are distended from inflammatory excitement before and after the part ulcerates, the protective covering,

it may be skin or mucous membrane, is destroyed, the underlying parts are exposed, and then granulation commences.

We can now also understand why a blood-clot effused on an exposed surface becomes vascular, and why a similar phenomenon is noticed in a dead inorganic substance such as "carbolised putty," under the same circumstances. The new vessels are simply pushed into these substances on account of their offering little resistance and being non-irritants. The same thing would occur in any substance of a similar nature if the above conditions were fulfilled.

Having thus expressed our views regarding the formation of granulations, let us consider what part they take in the healing process. To do this let us revert for a little to the examination of the parts in a wound healing typically by the second intention. We have previously observed that the bluish pink pellicle seen at its edge is the young epithelium spreading over the granulating surface. Before this occurs the granulations are greatly reduced in size, and indeed, at the immediate edge of the young epithelial covering, they are quite abortive. This atrophy takes place independently of the epithelial investment, for it ensues before the epithelium begins to spread. The completion of the epithelial investment is, in fact, a consequence of the reduction in size of the granulations. A wound with large flabby granulations will not heal. The epithelium, instead of organising and spreading over it, ulcerates and is destroyed. A typically healing wound presents granulations as small as is consistent with the removal of the restraining influence of the skin. The discharge of pus almost ceases—that is to say, the blood pressure is lessened, the leucocytes exuding from the capillary tufts become fewer in number, and then the epithelium rapidly closes in on all sides. The granulations, therefore, instead of aiding in the process of healing, are evidently one of the chief drawbacks to its occurrence, and must be removed before it can take place. We shall bring this out, however, more clearly immediately, when we consider how this atrophy of the granulating surface is effected.

Whenever a wound begins to heal there is found underlying the granulating surface a layer more or less dense, exactly corresponding to that seen on each side of a wound healing by

the first intention, after the lapse of a week or ten days, or to that noticed on each side of the pericardium in an organising fibrinous pericarditis. It is the *organising* layer, and is composed of spindle-shaped connective tissue elements, derived from the neighbouring fibrous tissue. The nuclei of the surrounding fibrous tissue are seen to be in a state of germination, and the resulting protoplasmic structures wander outwards and accumulate in this region, where they undergo elongation and subsequent fibrous transformation. The spindles which result surround the origins of the capillary loops, as shown in figure 4. The figure represents a horizontal section through a granulating wound at a level corresponding to the origins of the capillary tufts, and in it is represented two of these capillary vessels, surrounded by the spindle-cell tissue of the organising layer. The function of this organising layer is of extreme importance, for it not only contains the material out of which the future cicatrix is developed, but it serves another and very important purpose, in bringing about the atrophy of the granulating surface. As the spindle-cells become more organised they naturally contract on the capillary loops which they surround, and at first limit, but finally cut off, the blood entering them. This appearance is noticed in all typically healing wounds, before the epithelium begins to spread. The atrophy of the granulating surface is essential before the process can be completed, and it is mainly brought about by the constriction of its blood-vessels, from the organisation of connective tissue elements at its deepest part. When the granulations atrophy they diminish in volume, the leucocytes disappear in great part from around their vessels, and the vessels look more like fibrous processes than hollow channels. A certain number of connective tissue elements were originally carried upwards when the vessels sprung from their positions, and these now also aid in the process of organisation by becoming fibrillated. Finally, the epithelium begins to cover the wound, and it does so, not, as is generally supposed, by running over a granulation, but by passing round it; and this further aids, no doubt, in the process of strangulation (fig. 5). Total atrophy of the granulations follows, and then the epithelium covers the exposed surface at all points. It seems to spread merely as a consequence of the atrophy of the granulation tufts, and is not the primary factor in

bringing about their atrophy. That necessary result follows the constriction in the organising layer at the base of the granulating surface; and, when the granulations are sufficiently reduced in size to cease to act as an impediment to the epithelial extension, then the latter cannot be prevented from taking place and making the cicatrix complete. When it has entirely covered the exposed surface, any vessels which still remain in a distended condition, by the restraining action of the new epithelial covering, soon have their tendency to dilatation counteracted, and become of normal calibre.

The manner in which the new epithelium is generated is undoubtedly by division of young cells at the edge. It is a difficult matter to see, under ordinary circumstances, but with a little care, and especially by means of silver staining, the actual division of the cells can be clearly demonstrated. The theory propounded by Rindfleisch, Burkhardt, and others, that the young epithelium is regenerated from the connective tissue elements underlying it, although at first sight very fascinating and plausible, we must reject as totally untenable. We were at one time struck with certain appearances which seemed to support it, but, on closer examination, we did not find that they bore out what at first sight seemed probable. The fact that no one has ever been able to generate epithelium *de novo*, out of connective tissue elements, is a strong argument against it; and, looking at the question from an embryonal point of view, it seems out of keeping with all experience that the distinctive characters given to the three layers in the embryo should be violated in adult life. The epithelium is at first loosely attached to the organising connective tissue surface on which it lies, but processes are soon given off from the deepest epithelial cells, which pass into it, and constitute a firmer bond of union.

We are, therefore, for these various reasons, indisposed to grant that organisation takes place as a result of the epithelial extension; on the contrary, the reverse, namely, that the epithelium covers the surface as a result of the organisation being much more like the order of events. A skin graft will not take root on a granulating surface which is not in a healing condition. Before it will become fixed, the granulations must have undergone a certain amount of atrophy, and then the epithelium, apparently by

uniting with the organising layer of the wound, merely finishes the process of vascular destruction, and allows organisation to be completed. In effecting this, in the case of the skin graft, the same method is adopted as is seen in the young epithelium at the edge of a wound. The new epithelium is thrown out in long peninsulas, which run in the grooves between the granulations, and finally surround them. In this, as before, the epithelium does not rise to cover the granulations, but the granulations come down to meet the epithelium.

From what we have related in regard to the formation and structure of a granulating surface, it will be clear that, instead of looking upon the granulations as the means by which the healing of the wound is effected, we are irresistibly forced to consider them as one of the chief means by which healing is retarded. An exposed wound would and does heal without granulating, provided the superficial vessels, by accurately applied pressure, and by removal of all sources of irritation, are prevented from starting from their places. It was a common remark made to Mr Lister by those who came to see his cases when antiseptic surgery was younger than it is at present, that wounds treated on antiseptic principles were not "healthy-looking"—they were not granulating! The appearance which gave rise to that remark is now of every-day occurrence. If accurate pressure be applied, and if, by antiseptic measures, putrefactive sources of irritation be removed, an exposed wound does not granulate. On the contrary, a somewhat dirty grey pellicle forms on the surface, which, under ordinary circumstances, would be looked upon as indicating a sloughy condition of the wound; but nevertheless no sloughing is observed, the epithelium running over this in a marvellously short space of time. The dirty grey surface represents the organising layer seen at the deeper part of a granulating wound, and is composed almost entirely of spindle-cell connective tissue elements. It represents, in fact, one side of a wound healing by the *first* intention laid bare, and in which granulations have been prevented from forming.

Witness, for instance, what takes place in the cornea when it is wounded—a tissue in which there are no blood-vessels. The cornea may be looked upon as made up of interlacing bundles of fibrous tissue, rendered transparent in adaptation to a purpose;

and lying upon these bundles of fibres there are cells which we may designate as cornea cells or connective tissue corpuscles. It has been shown by Wyss how the repair of a solution of continuity in the cornea is brought about, and his observations have been confirmed by Gütterbock. He finds that, in non-perforating wounds of the cornea, healing takes place apparently more rapidly than in any other tissue in the body. In twenty-four hours after an incision has been made the epithelium has filled the superficial part of the wound. The young epithelium has no difficulty in covering this surface, as there are no granulations to prevent it, and the incised tissue belongs to a connective tissue type.

Another good example of the interference which granulations offer to the process of healing is to be seen in an ulcer with indurated edges. It is a fact daily verified, that an old wound with indurated edges and a granulating surface will not heal. What is the indurated edge due to? On examination, it is found to be simply a mass of granulation tissue underlying and retained by the epithelium. So long as this unorganisable material lies here, no healing can proceed; it acts like a foreign body, and must be removed to permit of organisation. The method found by the surgeon to be most serviceble in effecting this is to raise the limb so as to remove blood tension, and at the same time to apply pressure to aid in constricting the vessels, so as to limit the exudation of the blood leucocytes. We know, further, that a blister has the same effect; and probably the rationale of this treatment is, that the intense irritation caused by it excites the connective tissue in the neighbourhood to increased proliferation and organisation, this leading to constriction of the granulation vessels, on the principle enunciated at p. 536, and shown in fig. 4. The granulation leucocytes cease to be effused, those already effused being either cast off or absorbed; and, when the atrophy of the granulation tissue is complete, the connective tissue elements can then undergo complete fibrous organisation.

We would, therefore, conclude that in healing both by the first and by the second intention the process is identical, and that it simply consists in each tissue of the cicatrix being produced from a like tissue in the surrounding parts. All the

other phenomena seen in connection with the healing of wounds are either accidental or are mere adjuncts of the process. We cannot call the process of repair inflammatory in the ordinary sense of the term, as there is no untoward irritation; it is more like a reproduction of embryonic existence. Certain tissues, more especially the epithelial and white fibrous, still seem to have retained their embryonic vitality, and it is by the stimulation of these that the repair of the breach in the part is brought about.

We have directed some attention in this investigation to the alterations which take place in vessels after ligature, more especially in those which have been tied with catgut. The clot which is formed in an artery tied with catgut is particularly small and filiform in shape. We have observed this in several cases, and, judging comparatively, it seems as if the clot which is found after ligature with catgut in an antiseptic wound is usually smaller than that noticed after ligature with silk. It is totally insufficient to occlude the lumen, and hence, *a priori*, we would be led to doubt that the blood clot was the means by which its closure is effected. There is an element of fallacy connected with this observation, as in the organisation of blood clots elsewhere, which we must guard against.

It is a very remarkable and significant fact that the closure of natural blood-channels, such as the "ductus arteriosus" and the vessels of the pregnant uterus after parturition, is effected without the intervention of any blood clot, simply, apparently, by a thickening of the tunica intima. Friedländer's observations on this subject are specially worthy of attention, and we have been able to verify what he has recorded in connection with this matter. Blood-vascular channels which fall into disuse seem to undergo a natural endo-arteriitis which results in their occlusion. The great extent of this, both as a natural and as a morbid process, has within only the last few years been demonstrated by Heubner, Friedländer, Greenfield, Baumgarten, and others, and their investigations have thrown quite a new light upon certain lesions previously imperfectly understood.

All the observations that we have made serve to strengthen the conviction that the occlusion of the lumen of a ligatured

artery is brought about, under ordinary circumstances, by the thickening of the intima, and that it is a process similar to that observed in the arteries in certain cases of constitutional syphilis and other morbid conditions. The intervention of the blood clot is quite unnecessary; its leucocytes die, and do not assist in the formation of the cicatricial tissue which fills the vessel. The thickening in the inner coat of the artery is noticed for an inch to an inch and a half above the ligatured part, being more evident towards the point of occlusion. It is the same below the ligature as above it; and, in fact, unless from the occasional presence of blood within the part above, it is a matter of difficulty to say which is superior, which inferior.

Weber, however, has shown that the clot lying at the end of the vessel may become vascularised, and can be injected; and it might be urged that this is a sign of its becoming organised. We have frequently seen an appearance of this kind after ligature, where the inner and middle coats of the artery have been lacerated; but we believe that it is no more indicative of the organisation of the thrombus than the vascularisation of the blood-clot or "carbolised putty" over a wound is an indication of their organising. The same principle of granulation production holds good here as in other situations. An abraded surface results from the laceration caused by the ligature; the vasa vasorum are ligatured in their continuity, and the energy previously expended upon their main channels now comes to be exerted upon the collateral branches. This gives rise to their distension—a marked feature at the point of ligation, and wherever there is a free abraded surface they are thrown inwards as granulation loops. It is in this manner that the arterial thrombus becomes vascular, and the appearance of blood-vessels within the lumen of a ligatured artery is thus easily accounted for. It is nothing more than a granulating surface within the vessel. We have even seen an almost angiomatous plexus produced within the ligatured artery in this way, where no blood clot was present, or in which, at least, if there had been any, it had all become absorbed, nothing but a little pigment indicating its former presence. The thickening of the tunica intima goes on collaterally with this shooting out of granulation loops; and, as the cicatricial tissue in the intima becomes more fibrous, it contracts on the

granulation vessels and induces atrophy of them, in the same manner as in an ordinary granulating wound. The granulation vessels, however, serve a good purpose here in completing the occlusion of the lumen, for they carry with them a certain number of connective tissue elements, derived in all probability from the tunica intima; and when they begin to diminish in size these connective tissue elements, by organising, aid in the ultimate closure of the end of the vessel, and, in reality, render it complete.

Finally, the cicatrisation of the parts around the end of the artery is a most important factor in its occlusion, for by this means additional support is given to the ligatured end. This is specially important in arteries ligatured with catgut, where, after the catgut has been absorbed, nothing but the thickened intima and granulation tissue is usually present to resist the arterial blood pressure. Fortunately, if the wound be treated antiseptically, the completion of the surrounding cicatrix is usually well advanced before the ligature disappears, the cicatrix in this way very materially aiding in preventing secondary hæmorrhage. What the cause of the thickening of the tunica intima after ligature is we cannot definitely state, but, considering the laceration which it undergoes in ligature, it would seem that the irritation thus produced gives rise to a hyperplasia of its connective tissue corpuscles. It is also possible that the irritation caused by the blood being forced against the ligatured end may assist in bringing about this result. When the lumen of the vessel is totally obliterated the elastic layers disappear, and the whole structure of the arterial coats becomes blended with that of the surrounding cicatrix, so that the one can with difficulty be distinguished from the other.

We have made a series of observations and experiments in connection with the absorption of catgut when introduced into a wound, with the following results:—Catgut, when employed either as a ligature or as a drain becomes surrounded with the lymph that is at first thrown out on the exposed surfaces (fig. 1 *c*). This fixes it to the side of the wound, when it is used as a drain, and is found lying loosely upon it when used as a ligature or suture. It remains in this condition for a few days, and becomes in time enveloped by the connective tissue elements

out of which the cicatrix is generated. These pierce between its fibres to a certain length, but chiefly accumulate around it. It has, consequently, been suggested by Mr Lister that the absorption which it undergoes, in process of time, is due to the protoplasmic structures which surround and penetrate into it. There is, however, nothing remarkable in this appearance, and, under the circumstances, the presence of cellular structures within the catgut in a wound is only what would be expected. Ziegler has shown that if two glass plates placed in juxtaposition be introduced under the skin, cells not only pierce between them but organise into giant cells. In its absorption it seems to become first granular, then disintegrates, and disappears; and in from three weeks to a month there is not the slightest vestige of it, but only, as Mr Lister has described, a little fibrous thickening at the seat of ligature. Sometimes there is not even this to be noticed. We have sought in vain throughout a stump of the thigh, one month after operation, for any remains of the many ligatures used in ligation of the vessels.

We instituted a series of experiments some time since with catgut placed in different fluids, and kept at a body temperature, in order to see whether, independently of any vital action, they had the power of destroying it. A warm chamber was used, and the catgut introduced into the solutions was that ordinarily employed for ligature purposes, both carbolised and in its natural condition, this seeming to make very little difference in the experiments. The living tissues being naturally alkaline, it occurred to us to employ different salts contained within the blood, and to which it owes its alkalinity. Potassic phosphate was the one which at first naturally suggested itself as being perhaps of most importance, seeing that it is largely contained in the blood corpuscles. The solution employed was of the strength of 1 per cent. in water, and several pieces of catgut were placed in it, and then kept at a body temperature. We employed similar solutions of potash, acetic acid, and lime-water; and we also, as a crucial test, placed some of the catgut in fresh blood, keeping them all as before at a body temperature. In twenty-four hours that placed in the potash was partially dissolved, and the piece of gut was unfolded, that in the acetic acid was swollen, but not

otherwise altered. The others did not seem to have undergone any change. At the end of a week all that was left of the cutgut in the potash solution was a little shred, the greater part of it having become dissolved. That in the potassic phosphate, however, had become completely disintegrated, nothing but a little granular matter being left. That in lime-water showed no change, and did not do so up till the end of the experiments, that is to say, for two weeks. The acetic acid at the end of this time seemed to have had no further action than that noticed in twenty-four hours, while that which was placed in blood was, in about eight days, converted into granular débris, very much like that resulting from the action of potassic phosphate. The lime-water seemed to have very little solvent action. The agent which produced the most effective destruction was potassic phosphate.

While conducting these experiments, we found that L. Meyer had, during the last year, made similar experiments with lime-water and blood-serum. He states that in twenty-two days the catgut placed in lime-water became converted into a molecular mass, after its connective tissue fibres had become separated by solution of the "Kittsubstanz." Serum dissolved it also; but, according to him, required a longer time. He does not appear to have employed either blood or potassic phosphate. The explanation of its solution in alkalies must be that the albuminoids are converted into soluble alkali, albumens, and that the oily constituents are formed into an emulsion. In ligatures which we have examined taken from wounds, the two constituents that we found most abundant in them were albuminoid particles soluble in an alkali, and finely-divided oil globules soluble in ether.

We made some further experiments with the limb of a freshly killed animal, passing several catgut threads through it and keeping it, for a lengthened period, at a body temperature. In ten days we found that the cutgut within the soft parts had disappeared, and, in other respects, presented the same features as it would have done had it been placed in a living tissue.

We are, therefore, inclined to conclude that the disintegration of catgut in a living tissue is not a vital process, but is simply the result of a chemical action, consisting in the solution of the albuminoids and the emulsification of the oily constituents, and that

this is effected by means of the natural alkalinity of the tissue. We noticed one significant fact in these experiments (which perhaps might have some practical bearing, where it is desirable to obtain an animal ligature which will not undergo such rapid solution as ordinary catgut), namely, that the elastic fibres of the catgut resist the solvent action longest. Whether such a structure as the ligamentum nuchæ could be employed in this way we do not know; but if it could, there seems every reason to believe that it would withstand this "tissue digestion" longer than any other soft animal texture.

EXPLANATION OF THE PLATES.

Fig. 1. Side of a flap twenty-four hours after amputation. × 350 diams. *A*, fat cells of surrounding tissues. *B*, Extreme limit of the edge of the flap. *C*, The exudation on the surface.

Fig. 2. Portion of fascia from an incised wound of the neck, about three days after its infliction. × 480 diams. *A*, Connective tissue corpuscles lying between bundles of fibres cut transversely. *B*, Bundles of white fibrous tissue cut across. *C*, Connective tissue corpuscles in a state of division lying on bundles of white fibrous tissue.

Fig. 3. A granulation taken from a typically healing wound. × 480 diams. *A*, A capillary loop arising from a larger trunk underneath. *B*, Fibrous mesh-work around the capillary loop, containing leucocytes and some larger, probably connective tissue, elements. *C*, The large trunk from which the capillary loop has evidently been projected forwards.

Fig. 4. The deep or organising layer of a wound healing by the second intention. × 480 diams. *AA*, Two trunks of granulation vessels surrounded by spindle-cell tissue. *B*, Spindle-cell tissue, of which the organising layer consists, in process of contraction around the enclosed vessels.

ON THE DENTITION OF *HYPSIPRYMNUS (BETTONGIA) PENICILLATUS*, GRAY. By GEORGE LESLIE, *Demonstrator of Zoology in the University of Edinburgh.*

AMONG a series of skulls of monotremes and marsupials collected in South Queensland by Mr T. L. Bancroft, student of medicine in the University of Edinburgh, and kindly presented by him to the writer, is one labelled *Bettongia Ogilbyi*, the dentition of which merits description as exhibiting a remarkable asymmetrical development of the permanent teeth. *Bettongia Ogilbyi* is regarded by Waterhouse[1] as not distinct from *Hypsiprymnus penicillatus* (Gray). The greatest length of the skull measured from the supra-occipital ridge to the anterior extremities of the nasal bones is 7·8 centimetres, the greatest width, a little behind the middle of the zygomatic arches, is 4·5 centimetres.

In the right premaxilla there are the usual three incisors, and separated from these by a very short diastema the alveolus for the canine, the tooth is, however, lost in this specimen. This alveolus is situated in the suture between the premaxilla and maxilla. In the right maxilla a diastema, 7 mm. in length, separates the alveolus for the canine from that of the first tooth of the molar set, which is the permanent premolar. This tooth is chisel-shaped, much elongated in the antero-posterior direction, along which it measures 7 mm. Its external and internal surfaces are marked by seven vertical sulci, producing nine well-marked ridges, of which the anterior and posterior are the largest. Behind this are the four molars resembling each other, but differing remarkably in shape and size from the premolar. Each is square on transverse section, having the grinding surface marked by a deep transverse, and a more shallow longitudinal groove, so that four cusps are produced. The internal cusps of the first molar are worn down to flat surfaces, those of the second are also worn, but to a less degree, while all four cusps of the third molar are fresh and sharp. The fourth molar is only protruding above the alveolus, but it also exhibits four cusps. These teeth fully

[1] *Nat. Hist. of Mammalia*, vol. i. p. 214.

occupy the alveolar margin of the maxilla, the posterior molar lying external to the horizontal plate of the palate bone, which is in this specimen a slender transverse bar, separated from the palatal plate of the maxilla by a large hiatus.

In the right ramus of the mandible, as in the right side of the upper jaw, the teeth have the usual arrangement characteristic of the adult dentition of this genus. The trenchant premolar corresponds in size and position to that of the maxilla, and behind it are four molars, the anterior of which is evidently the oldest, while the posterior molar, instead of having four cusps, is seen as a small rounded tubercle just appearing above the alveolus. The dental formula of this specimen is, therefore, for the right side

$$i\,\frac{3}{1}\;c\,\frac{1}{0}\;pm\,\frac{1}{1}\;m\,\frac{4}{4}.$$

This formula is, however, not that of the left side. The canine of the upper jaw and the incisors of the upper and lower agree perfectly with those of the right side, but instead of a single premolar, there are two in both jaws. The first premolar resembles in form that which has been described, but it is smaller, its length being only 4 mm., and it exhibits on its outer surface only five vertical grooves. The tooth behind this is similar to the molars of the opposite side. It is smaller and much more worn than these, the transverse and longitudinal ridges having been obliterated, leaving a simple, smooth flat surface. Posterior to this are four molars in no wise differing from those of the opposite side.

The alveolar border of the left ramus of the mandible shows a corresponding arrangement of teeth. Behind the incisor is a small grooved chisel-shaped premolar, and this is succeeded by five quadrate teeth of the ordinary type. The posterior molar of the left side exhibits a more advanced stage of development than that of the right. It has grown considerably above the alveolus, and its four cusps are well marked; the dental formula of the left side is therefore—

$$i\,\frac{3}{1}\;c\,\frac{1}{0}\;dm\,\frac{2}{2}\;m\,\frac{4}{4}.$$

When that portion of the facial surface of the maxilla which

formed the outer wall of the alveoli for the premolars was removed, the cause of this irregular dentition was seen. Immediately above the first two teeth of the posterior set, and having its lower edge embraced by their fangs, was a large tooth, exactly resembling in size and shape the single premolar of the opposite side. A corresponding tooth was also seen on section of the left ramus of the mandible. If these teeth had come into position, they would each have replaced the two anterior teeth which are, therefore, deciduous molars, and the dentition of the animal would have had the usual formula of the species, viz.—

$$i\,\frac{3-3}{1-1}\;c\,\frac{1-1}{0-0}\;pm\,\frac{1-1}{1-1}\;m\,\frac{4-4}{4-4}.$$

The replacement of the two deciduous molars by a single premolar, in the genus *Hypsiprymnus* was long ago pointed out by Professor Owen;[1] and Professor Flower in his memoir on the succession of teeth in the marsupialia[2] has figured the skull, showing these being replaced. The chief interest of the present specimen lies in the fact of the right side of the skull exhibiting the fully-formed adult dentition, while on the left the deciduous molars are still in position, showing no signs of decay. It would be interesting to learn whether this is to be regarded as an individual peculiarity, or as a constant phenomenon in this species.

[1] *Cyclop. Anat. and Physiol.* Art. "Teeth," vol. iv. p. 933.
[2] *Phil. Trans.* vol. clvii. Pl. xxix.

NEW THEORY OF CONTRACTION OF STRIATED MUSCLE, AND DEMONSTRATION OF THE COMPOSITION OF THE BROAD DARK BANDS.

By DAVID NEWMAN, M.B., *Pathological Chemist, Western Infirmary, Glasgow.* (PLATES XXV., XXVI.)

(*From the Physiological Laboratory, Leipzig.*)

IN this paper we shall advance a new theory regarding the minute histological changes which take place in striated muscle during contraction, and endeavour to demonstrate the composition of the broad dark bands.

Before entering upon the subject, however, it will be necessary to say a few words regarding the histology of voluntary muscle, and state very briefly the views held respecting its chemical composition, and the theories advanced to explain the process by which contraction is accomplished.

In its minute structure, a voluntary muscle is described as being composed of two elements—(1) a tube, consisting of an elastic, completely-closed membrane, the sarcolemma; and (2) the sarcous elements, which are united longitudinally to form fibrillæ, whilst transversely they may be separated into discs corresponding in thickness to the distance between the transverse striæ and the sarcous elements. As Bowman observes, "It is as proper to say the fibre is a pile of discs as that it is a bundle of fibrillæ, but, in fact, it is neither the one nor the other, but a mass in whose structure there is an intimation of the existence of both, and a tendency to cleave in the two directions. If there were a general disintegration along all the lines in both directions, there would result a series of particles, which may be termed *primitive particles* or *sarcous elements*, the union of which constitute the mass of the fibre. These elementary particles are arranged and united together in two directions, and the resulting discs, as well as fibrillæ, are equal to one another in size, and contain an equal number of particles. The same particles compose both. To ~~detach an entire~~ fibrillæ is to abstract a particle from every disc, and *vice versa*." The fibrillæ are, therefore, elements superimposed, whilst the discs are made up of a number placed side by side in the same plane. The binding of

the elements longitudinally is much more intimate and firmer than their union with each other transversely. Thus, it is by no means difficult to separate the fibrillæ of a living muscle from one another, whereas it is almost impossible to procure a preparation of such where the elements are separated transversely. Kölliker does not agree with this conception of the arrangement of the muscular elements, but is of opinion that the fibrils preexist as such, to which he has given the name of *muscle-columns.*

The muscular fibres of the frog may be divided, as regards their transverse measurement, into two distinct sets, small fibres measuring from 0·0200 to 0·0250 mm., and larger fibres varying from 0·110 to 0·137 mm. in diameter. These measurements are difficult to fix absolutely, owing to the alterations in the breadth of the fibre in its contracted state as compared with what is observed when it is relaxed. This source of error has, however, been guarded against by making the measurements in each as nearly under the same circumstances as possible. These two sets of fibres are intermingled with one another, so that the smaller fibres are found on each side of the larger, as shown in fig. 1 (B.B. the small fibres, A. the large). The difference between these two varieties of fibres in other respects will be referred to further on.

A point of interest may be mentioned here, namely, that it is principally to the small fibres that the nerves pass. The small adhere more firmly to the large fibres with which they are associated than with other surrounding fibres; therefore, in teasing out a fasciculus there is no difficulty in separating the larger fibres from one another, but even though the greatest care be taken a considerable number of the small are found to be in close contact with their corresponding large fibres, so much so that they have the appearance of being within a common sheath. This can, however, be easily shown not to be the case, by taking a still living muscular fibre, place it on a slide, dry, and, after laying a cover-glass over it, add a drop of distilled water, when, owing to irregular contraction of the fibrillæ, the sarcolemma is thrown into folds and the smaller fibre becomes separated at intervals; or, again, if the sarcous elements of the larger fibre are broken and separated into two distinct portions, the sarco-

lemma becomes contracted and separates itself from the small fibre lying alongside.

When viewed by transmitted light, with a sufficiently high magnifying power, the muscular substance shows a double striation, longitudinal and transverse, due in part to the arrangement of the sarcous elements, so that under certain circumstances, to be referred to hereafter, either one or other may be obliterated as a result of changes in the muscular substance. When the muscle is in a favourable state for examination, the transverse striation exists not only throughout a proportionately thick, alternating, clear, and dark portion, but the dark striation is separated by a small, cross, lighter part, which, again, is traversed by a very thin dark band. This clear band is not continuous in the whole breadth of the fibre, but, like the broad clear bands, is interrupted at regular intervals by dark points corresponding with the longitudinal striation. The broad light bands are also divided into two equal portions by a dark band, the *thin dark lines.*

Before going further it will be necessary to explain an expression about to be used in connection with the measurement of the transverse striation. When such an expression as 7=·0172 mm. occurs, it is meant to express that there are seven light and seven dark bands in the ·0172 of a mm.

Let us now examine, before discussing the various theories regarding muscular contraction, the microscopic appearances of muscle in its different conditions. A muscle may be said to be in one of four states—(1) shortened and at rest; (2) stretched and contracted; (3) expanded and at rest; or (4) shortened and contracted. In order to study the position of the various elements of the muscle in these four conditions, it is necessary to have a reagent which has the power of fixing them in whatever form it is desired to examine them. Osmic acid fulfils this requirement admirably, and may be employed in the following manner:—Take one of the small muscles from the front of a frog's leg, and having placed it in such a position that it is at its greatest contraction, pass two ligatures round the tibia, so that one includes the upper, the other the lower extremity of the muscle, remove the tibia from the body of the frog along with the fixed muscle, and place it for half a minute in 2 per cent. and

afterwards in $\frac{1}{2}$ per cent. osmic acid solution. In a few minutes the whole muscle becomes stained and firm. The condition of the muscle, *shortened and at rest,* may now be examined. By carefully teasing out the fibres and separating the fibrillæ as much as possible, they will show a clearly-defined cross striation formed by alternating clear and dark stripes, which are of equal breadth from the one end to the other. The broad, dark, transverse bands are narrower than the light ones, single, and the thin, dark lines are invisible. The striation is $9 = \cdot 0172$ mm., whilst the longitudinal striation is moderately well marked (fig. 2). Such is the condition when a contracted muscular *fibre* is examined. Remarks regarding the appearance of the individual *fibrillæ* will be at present postponed until the other conditions of muscle are examined.

In order to procure a preparation of a muscle where the fibres are extended, and at the same time contraction taking place (*stretched and contracted*), the same mode as above described may be adopted, the only difference being that the muscle, instead of being fixed so as to permit of shortening taking place, is tied in a fully-extended position, and, besides, immediately previous to, and for a short time after it is placed in osmic acid, the muscle is tetanised by means of an induction apparatus.

When a fibre of this muscle is examined it will be found that almost the whole details of the structure of muscle are visible, namely, the thin dark lines, the clear spaces, and the broad dark bands; the latter, however, are very considerably narrowed, single, and, moreover, the longitudinal striation is very distinctly marked. The proportion between the breadth of the light and dark bands is considerably altered from what is observed in muscle which has not undergone contraction, and as a result the thin dark lines are almost as broad as the broad dark bands. This condition is represented in fig. 3. In this figure the transverse striation is seen passing straight across the muscle. This is, however, not always the case, as frequently the dark bands are observed to pass obliquely, as shown in fig. 7, which is intended to represent the fibrillæ of a fibre in which the dark bands are so disposed. Usually the dark bands of fibrillæ so affected lie parallel to each other (fig. 7); at other times, however, they are noticed to be placed at right angles to one another.

In preparing a muscle for examination in the extended condition (*expanded and at rest*), the same mode of procedure may be adopted, only that the electric apparatus is not employed. In the fibres of this muscle the whole details of the histological structure of muscle can be made out. The thin dark lines, clear spaces, and the thick dark bands, which are double, equal, if not greater, in breadth than twice that of the clear space situated between them and the first thin dark line. The longitudinal striation is almost, if not entirely, invisible.

The fourth variety, the *shortened and contracted* muscle, presents very much the same appearance as the shortened and at rest.

Although the condition of the relationship of the different elements constituting a muscular fibre in muscles fully expanded and those which are stretched and contracted are of considerable importance in helping to explain the physiology of muscular contraction, yet it is to the study of the distinctions which exist between the shortened and contracted and the expanded muscle at rest that we look most for light on the subject. We shall, therefore, contrast these two conditions more in detail—first, the examination of the fibre taken as a whole, and secondly, the isolated fibrillæ and their component parts.

In examining a fibre where the striation 6=·0172 mm., one can easily satisfy himself of the following appearances:—It will be noticed (fig. 4) that the fibre is traversed by narrow dark lines, (1) the basal membranes or transverse lines of Krause, which are distant from one another about ·0028 mm. The interspaces between these two thin lines are filled up by broad dark bands, (2) the *haupt-substanz* of Dobie, anisotropic material or *disdiaklasten* of Krause. These broad dark bands measure about ·0015 mm. On each side of these bands, between them and the thin transverse lines, are clear light bands, (3) *zwischensubstanz* of Dobie, isotropic or muskel-kästchen fluid of Krause, which measure ·00065 mm. individually. These bands stretch across the fibre in straight lines with very little, if any, interruption. The broad dark bands (2) are not, however, simple bars, but are more complicated in their nature. When seen in the fibre they are found to be divided into two portions by lighter bands, which in their turn are observed to be traversed by other

thin dark lines, which divides them into two equal parts. If, however, instead of examining these bars in the fibre we study their appearance in individual fibrillæ lying alongside, not superimposed upon one another, they will be seen to be divided only by light spaces, the narrow dark lines having entirely disappeared. It is further to be observed that in focusing the microscope the first points that appear clearly defined in connection with the broad dark bands are the marginal portions, in the form of two dark lines separated by the clear interspace above referred to; but when the focus is lowered the clearness of the light portion is diminished by apparent broadening of the dark lines, although it is still quite perceptible. So much for the appearance of a *fibre* in a state of *rest*. Let us now consider the appearances of a *fibre* which is *shortened* and *contracted*. In this case take a muscle where the striation is 9=·0172 mm. (figs. 2 and 8). Here it will be seen that the fibre presents a much less complicated appearance; it consists simply of an arrangement of alternating light and dark bands, the latter being narrower than the former, and, therefore, differing essentially in their proportional breadth from what was seen in the muscle in a state of rest. If the breadth of the bands in this, the contracted, be contrasted side by side with those of the relaxed muscle, it will be seen, without doubt, that not only have the clear bands also participated in the contraction, but, further, that the fibrillæ are greater diameter in the former than in the latter. This may be easily done by carefully teasing out fibres of contracted and relaxed muscle, mixing them together, and examining under a high magnifying power, when two or more of the different fibrillæ are almost sure to be in juxtaposition, so that they may be readily contrasted with one another. Moreover, besides the difference as regards the bars, it is to be observed that whereas in the muscle at rest the longitudinal striation is ill-defined, and in some fibres not to be detected at all, in the contracted muscle it is well marked.

The contrast between the muscle that is *stretched* and *contracted* (figs. 3 and 6) and the above is very striking. Like the muscle which is expanded and at rest, the broad dark transverse bars are separated considerably from one another: in a muscle where the striation is 6=·0172 mm., the intervals between the

broad dark bands are about ·0023 mm., so that the breadth of the dark bands (2) is only ·0005 mm., whereas in the muscle which is at rest the intervals between the broad bands is ·0013 mm., whilst the bands themselves equal ·0015 mm. in diameter. In both these states the thin basal lines (1) are well marked. The broad dark bands of the contracted and stretched resemble the same bars of the contracted and shortened muscle, and differ from those of a muscle in a state of rest, in so far that they are very narrow (·0005 mm.), single, there being no evidence of a dividing clear space.

Let us now study the appearances presented by the individual *fibrillæ* in the various conditions above described; consider first those of the muscle *extended* and at *rest*. It has already been pointed out that when muscle is examined in this state, all the histological details may be demonstrated (figs. 4 and 5)—the thin dark lines (1); the broad dark bands, with their double contour (2); and the clear bands (3). The longitudinal markings are, however, invisible. Fig. 5 represents two fibrillæ of such a muscle. The striation is equal to 6 = ·0172 mm. The distance between the thin dark lines (1) equals ·0028 mm.; the spaces occupied by the light isotropic substance (3), situated between the thin dark lines and the broad dark bands, are ·00065 mm., and the diameter of the fibrillæ ·002 mm. It is to be remarked that the contour of the fibrillæ is quite straight from end to end, or, in other words, the diameter is uniform throughout. The anisotropic substance constituting the broad dark bands (2) will be observed to offer a double contour, the marginal being much darker than the intermediate portion, and when the sides of these little bodies, which are ·0015 mm. from end to end, are carefully examined, it will be seen that there is a gradual constriction, which attains its maximum towards the centre, so that the anisotropic particles present the appearance of cylinders, the sides of which are ellipted.

When the *stretched* and *contracted* muscle is examined (figs. 3 and 6), it will be found that the thin dark lines and clear spaces are distinctly visible, but, in contradistinction to the above, the anisotropic substance presents only a single contour, and the longitudinal striation is distinct. Fig. 6 shows the appearance of a single fibrilla of such a muscle—striation,

6=·0172. The distance between the thin dark lines (1) is the same as in the muscle extended and at rest, namely, ·0028 mm., but the elements contained in this interspace are somewhat differently disposed. Thus the space occupied by the clear substance, measuring between the broad dark band (2) and the thin dark line (1), is ·0005, instead of ·00065 mm., and the dark bands (2) are ·0005 mm. in diameter, in the place of ·0015. There is, however, another point to be attended to, and that is the alteration in the diameter of the fibrillæ. At points corresponding with the thin dark lines, this measurement is equal to ·002 mm., or even less, whereas at a point agreeing with the situation of the broad dark bands the diameter is ·0028 mm. Moreover, the anisotropic substance no longer shows the appearance of an ellipted cylinder with its double contour, but now resembles a thin flattened disc. The only other conditions which we have now to refer to are *shortened* and *contracted* and *shortened* and at *rest* muscle (figs. 2 and 8). The appearances presented by the fibrillæ in these two states are exactly the same, as far as microscopic examination can detect. It has been already stated that when fibres of these muscles are examined (fig. 2), the thin dark lines are invisible, the broad dark bands are considerably narrowed, single, and the longitudinal striation is unusually distinct. Fig. 8 represents the appearance of an individual fibrilla. Striation is 9=·0172 mm. It will be observed that, like the fibrillæ of the stretched and contracted muscle (fig. 6), the diameter is not the same throughout, but there are nodes or projections corresponding in situation to the broad dark bands. At these points the transverse measurement is ·0037 mm., and at the narrowest parts, agreeing with the situation of the thin dark lines, which are, however, invisible, it is about ·003 mm. The breadth of the broad dark bands equals ·0005, and the clear spaces ·0014 mm.

Regarding the substance of which the fibrils of muscle are composed, and the interpretation of the various appearances, there is room for considerable difference of opinion. We have already referred to Bowman's theory, that the sub-division of the fibre into fibrillæ, and the cleavage of it transversely, is due to a disintegration which may take place in either one or other direction, resulting on the one hand in the production of fibrillæ,

on the other of discs, so that if the division were to take place in both directions, minute particles, the "sarcous elements," would be obtained. Other observers, such as Schwann, Dobie, Kölliker, hold to the opinion that the fibrils pre-exist as such, and which, when collected into definite bundles, constitute what the latter observer calls "muscle columns." Each fibre (muskel-spindel), according to Krause,[1] consists, independent of sarcolemma, of a large number of small boxes (muskel-kästchen), which are included between the two thin dark lines. These compartments are bound by a membrane, and filled by a fluid (*muskel-kästchen* fluid, or isotropic material), in which a muscle prism (sarcous element, anisotropic substance) floats. The form of the prism is that of a multangular column, the transverse diameter of which varies, whilst the length of the prism remains constant. Each *kästchen* possesses a basal membrane, represented by the thin transverse line, and a single lateral membrane, investing it annularly, which unites with the basal membrane to complete the compartment. Krause's theory of the mechanism of muscular contraction is as follows:—"With regard to the contraction of muscular fibre, it is to be remarked that, even in complete physiological contraction, the breadth of the anisotropic bars are not measurably affected, the length of the muscular columns remain constant, whilst the breadth of the isotropic transverse bars diminishes. This signifies that the *muskel-kästchen* fluid permeates between the muscle columns. These last are fixed in their form, and are physiologically unchangeable bodies, arranged as bands of electro-motor end plains, which bands can draw themselves by contraction in different directions. The muscular prisms are comparable to bundles of temporarily magnetised iron rods. The optical appearances of the transition stages explain themselves simply by the bending of the anisotropic substance." Fig. 9 represents the changes in the various states of the muscle.

"A, In an uncontracted condition; *an*, a muscle prism, consisting of a bundle of muscle tubes or columns, or *disdiaklasten is*, *muskel-kästchen* fluid, or isotropic substance; Q, transverse lines, or basement membrane of *muskel-kästchen*. B, In a con-

[1] Krause, "Über den Bau der quergestreiften Muskelfaser" (*Zeitsch. f. ration. Medicin*, 1868, s. 265 u. 1869 s. iii.).

tracted condition after an earlier idea (assumption). The muscle prism is unchanged, but the *muskel-kästchen* becomes broader and lower, the *muskel-kästchen* fluid is in part disposed between the lateral membrane of the *muskel-kästchen* and the muscle prisms, of which the natural observation reveals nothing. C, The contracted position after the now accepted supposition, *kästchen* as in B. The rods are separated a little from each other by the *muskel-kästchen* fluid; the clear spaces of the isotropic substance are therefore lower, the muscular prisms broader."

Merkel,[1] who takes the same view as Krause,[2] regards the thin dark lines as partitions separating the *kästchens* from one another, but in respect to the nature of the substance contained therein, he does not regard it as consisting of a fluid and solid mass, but of a consistent though nevertheless movable substance. When the muscle is in a state of rest, he supposes this substance to accumulate on both sides of the thin dark line, so forming the broad bands. If, on the other hand, it is contracted, this substance separates from the thin lines, and accumulates round the thin sheath in the centre of the broad dark bands, which he regards as a partition separating the kästchen of Krause into two distinct portions.

Brücke, on theoretical grounds, conceives the anisotropic substance to be made up of an aggregation of minute double refractive bodies, termed *disdiaklasten*, which he supposes to lie in rows or grouped in columns. Thus, if a muscular fibrilla be represented in a state of rest by four rows of these molecules, with four abreast in each row, then the condition during contraction would be described by two rows with eight abreast, so would the length of the fibrilla and the muscular bundle be shortened.

Engelmann[3] agrees with Krause that there is a disappearance of the clear fluid from the light bands; but whilst Krause maintains that the dark bands remain unaltered, Engelmann, on the other hand, believes that they form the essential agents of con-

[1] Merkel, Der quergestreite Muskel (*Arch. f. Mikrosk Anatomie*, s. 244, 1872).

[2] *Handbuch der menschlichen Anatomie*, s. 72, Krause, 1876.

[3] Engelmann (*Pflüger's Archiv*, s. 33, 1873).

traction, and supposes that the clear bands correspond to a fluid substance, which, at the moment of contraction, enters into the dark bands by a process of imbibition, whilst, at the same time, the dark bands undergo contraction.

We have still to consider briefly the appearance of muscular fibre in polarised light, and as we agree with Brücke[1] in regard to facts, we will quote his own words: "If the muscles contract, the fibres are seen to become thicker, and the transverse striæ to approximate. Each sarcous element must, consequently, change its form, and become shorter and thicker. If such a change of form result from any force acting in an elementary solid body, the operation of that force must extend as far as the individual molecules, the optic constants must be changed, and it is not conceivable that any should be so changed that the ordinary and extraordinary rays, after they have traversed equal thicknesses in the same direction, should present again the same difference of velocity that they offered under similar circumstances before the change of form.

But it is quite a different matter if the sarcous elements are groups of solid doubly refracting bodies, of which each individual remains unchanged in form in the act of contraction. The form of the group—that is, of the sarcous element—is here changed by an alteration of the arrangement of the several corpuscles, just as in a company of soldiers, groups of various breadths and depths are produced by changes in the position of the several individuals. In the latter case, the optic constants are not altered in the act of contraction, and the rays on this account, if they have traversed equal thicknesses in the same direction, must constantly exhibit the same differences in velocity, whether the muscle be in the relaxed or in the contracted condition.

Since we have a measure of the difference of velocity in the colours which appear under the polarising microscope, we are enabled to answer the question experimentally, whether the optic constants of the contractile substance change during contraction to any considerable extent or not. All the investigations I have directed to this point have had a negative result,

[1] E. Brücke (vol. i. p. 239, Stricker's *Human and Comparative Histology*, New Sydenham Society Translation, 1870).

i.e., I have never seen any alteration of colour that could be entirely referred either to changes in the thickness of the layer traversed, or in the angle which the rays undergoing interference make with their optic axis. As, therefore, I have in vain sought after a change of the optic constants, I must maintain that the sarcous elements are not elementary and simple solid bodies, but groups of smaller doubly refractile bodies." To these bodies he has given the name of disdiaklasts.

If the muscle of a living frog be frozen, and examined in this state by the polarising microscope, no striation can be detected, and the whole of the muscular substance appears doubly refractive; whereas, if the temperature be allowed to rise slightly, the broad dark doubly-refractive bands will gradually become evident, whilst the alternating clear spaces only possess powers of single refraction.

In considering the explanation of the phenomenon of muscular contraction, it seems to us that the following four points should be attended to, and their presence or absence accounted for and interpreted:—

I. *The absence of transverse striation during perfect rest; its gradual appearance, first as a broad dark transverse bar with a double contour, afterwards becoming narrow, the breadth being in an inverse ratio to the amount of contraction; also, that during a state of rest the whole fibre appears doubly refractive, and that only when contraction has taken place the alternating stripes possess the property of single refraction.*

II. *The diminution of the longitudinal as associated with increase in the transverse measurement of the muscle, without any loss of volume.*

III. *The absence of longitudinal striation in a state of rest, and its appearance during contraction of the muscle.*

IV. *The appearance of the thin dark lines or basal membranes in relaxed muscle, and in muscle that is stretched and contracted, and their absence when muscle is shortened and contracted.*

Before discussing these points it will be necessary to consider shortly the chemical composition of muscle, and describe a few experiments performed with the object of demonstrating the component parts of the dark bands.

Muscular fibre may be said to be composed of two parts,—the

muscle plasma and an insoluble residue. The former may be readily obtained by freezing *dead* frog's muscle, from the vessels of which the blood has been carefully removed, reducing it to a powder, and mixing it with four times its weight of snow, containing 1 per cent. of chloride of sodium. This mixture may be filtered at 0° C., when it will be found to present the appearance of an opalescent fluid. If the temperature be now raised it will be found to coagulate and separate itself into two portions —*muscle clot* or *myosin*, and muscle serum. Myosin is a proteid, soluble in dilute saline solutions, from which it may be again coagulated by heat, or the prolonged action of alcohol, and precipitated by excess of chloride of sodium. It is soluble in weak hydrochloric acid. Acids convert it into an altered substance—syntonin or acid-albumin; while with dilute alkalies it forms alkali-albumin. The serum consists of albuminates, animal ferments, colouring matter, and various nitrogenous proximate principles, amongst which may be mentioned creatine, creatinine, xanthine, hypoxanthine, dextrin, urea, also inosic, paralactic, and urinic acids. To the consideration of these and other substances found in muscle, we cannot afford space, nor is it necessary to refer to them here. According to Von Bibra, the following is a quantitative analysis of frogs' muscle in 1000 parts:—

Water		804·3
Solids—		
Albumin	18·6	
Gelatinous matter	24·8	
Alcoholic extract	34·6	
Fat	1·0	
Vessels, &c.	116·7	
		195·7
		1000·0

We have already referred to the two apparently distinct elements—the light and the dark bands—which differ from one another in the manner in which they refract light, the sarcous elements being anisotropic, whilst the substance which unites the discs is singly refractive. It is to the physiology and

chemistry of these bodies that we now desire to call attention, previous to discussing the conclusions to be inferred therefrom.

If a few fibres of a still living frog's muscle be placed on a dry glass slide, covered by a cover-glass, and examined with a magnifying power of 250 to 300 diameters, it will be found that in some of the fibres the longitudinal markings are very distinct, whilst in others they are entirely lost. The same remark may be made in reference to the transverse striation. It is, however, to be observed that both may be absent or present; but the general rule is, when the transverse striation is broad and its characters well marked, the longitudinal is ill defined or absent; whereas, when the longitudinal striation is distinct, the transverse shows evidence of contraction. Supposing we allow, while the muscular fibres are still alive, a very weak solution of an acid or alkali (1 per cent.) to be passed under the cover-glass, and again examine, it will be found that certain changes have taken place. The transverse striation in most of the fibres, more particularly the smaller (fig. 1, B), is completely destroyed. A considerable number of the fibres will be found to have lost their essential characteristics; the fibres retain their shape, and the sarcolemma is intact, but the fibrillæ and transverse striation are no longer to be discerned. The muscular fibre so altered presents the appearance represented in figs. 10 and 11. The sarcolemma is complete, the fibrillæ are almost or entirely invisible, and, as shown in the upper side of fig. 10, the histological structure may be completely destroyed. Where these changes have taken place a new form manifests itself in the shape of small spheroidal, or irregular-shaped highly refractive bodies, which are, so long as the structure of the muscle is not entirely destroyed (figs. 12 and 13), deposited in rows corresponding with the direction of the fibrillæ, and also with the situation of the broad transverse bands. With a power of 250 to 300 diameters, the relationship to the longitudinal striation can be easily made out, but it requires a power of from 500 to 1000 to make out the position in reference to the transverse bands. This is shown pretty well in fig. 10. The lower portion of this figure represents these small globular bodies as seen lying in the broad dark transverse bars, which are broad and well marked. When living muscle is placed in 1 per cent. hydro-

chloric acid solution, washed with water, and placed in ½ per cent. osmic acid for a few hours, we have sometimes succeeded in separating a fibrilla containing these little globular masses. Their appearance is represented in fig. 14. A, the fibrilla of an uncontracted muscular fibre; striation, $5\frac{1}{2} = \cdot 0172$ mm. B, thin dark line; and C, globules which appear to float about free in the *muskel-kästchens*. In fibres where the changes have only advanced to a slight degree—where the histological elements are still to be made out—the globular bodies are small, and their position in regard to the longitudinal and transverse striæ regular and definite; but when the elements of the muscle are destroyed, then these bodies are larger, and distributed within the sarcolemma without any apparent regard to arrangement. The upper portion of fig. 10 represents this latter condition. It will be observed that the transverse striation is absent, the globules are large and numerous, and although there is a correspondence in their position to the situation of the dark transverse bars and longitudinal striation in some places, yet where the histological markings are most destroyed this relationship is lost.

Take a frog that has just been killed by destroying the brain and spinal cord. An incision having been made through the skin, one of the long muscles of the thigh should be exposed, and a deep cut made into the muscle parallel to the fibres. Then laying hold of the edges of the incision with a small pair of forceps, the aponeurosis may be drawn off with a few of the underlying primitive bundles. Putting these aside, apply the forceps anew, and raise from the exposed surface a sufficient number of fibres: these will be found to detach themselves from one another in shreds. The next thing to do is to place underneath these fibres a narrow glass slide; then cover with a cover-glass, cut the muscle on each side of the glass slide, and protect the fibres from evaporation by touching the edge of the cover-glass with paraffin. If, however, the examination is not to be protracted, or supposing reagents are to be added, omit the paraffin. If the still living muscle, so mounted, be now examined in the extended condition without the addition of any medium, the dark and light bars will be seen (striation $5\frac{1}{2}$ to $6 = \cdot 0172$ mm.), the dark bars being usually a little broader than the light. These bars extend straight across the muscle, and are

perfectly regular as regards the breadth of the individual bands, but the striation may vary slightly in the course of the fibre. When reagents, such as soda solution (·1 per cent.), hydrochloric acid (·1 per cent.), or even distilled water, are added, changes are produced—the first being a tendency to increase in the diameter of the fibre. Contemporaneous with this change, it will be noticed that the longitudinal striation, which was before invisible, now manifests itself, and at the same time the transverse bars assume a curved appearance, due to more rapid contraction of the fibrillæ at the centre as compared with those at the side of the fibre. After contraction, one of two results may follow, depending upon the degree to which contraction has taken place. (1.) Supposing the contraction is slight, the longitudinal markings will not become very pronounced; the dark transverse bars will only undergo slight diminution in breadth and approximation, and will afterwards relax into their former state without disappearing. (2.) If, however, it is great, the longitudinal striation becomes very distinct, so that the fibrillæ appear to separate from one another, the dark transverse bands become narrow and closely approximated, after which they may return to their former state or disappear. This is well seen when the extreme contraction is localised to a small portion of a fibre, as shown in fig. 15. A, transverse striation is still seen, but very faint, 12 = ·0172 mm. B, striation completely lost, with only a slight clouding and one or two granules. The appearance of the little globules, when muscle is treated with a weak acid or alkali, seems to take place in the following manner:—In a broad dark band, after contraction has taken place, a small square-shaped body appears, which does not refract light so much as the dark bar. This small mass occupies at first the whole breadth of the dark band, but subsequently undergoes contraction till ultimately it is only about half of its former size. According as its size diminishes, its power of refraction increases.

Their gradual development can be more readily studied if a few fibres of a frozen muscle be taken and placed upon a cooled glass slide, to which two small pieces of platinum foil has been attached. The pieces of foil are arranged so that there is a space of about a quarter of an inch between them. It is in this space that the fibres are placed, after which the whole may be covered

by a thin cover-glass, and examined under a power of 1000 diameters. An arrangement is now made, to pass by means of the platinum foil an interrupted current through the fibre. If the fibres be examined while still frozen, or only slightly above the freezing-point, it will be observed that there is no evidence of transverse striation; but if the temperature be allowed to rise, and at the same time a very weak induction current be passed through the fibre, the transverse striation will be developed, and at the same time the globules will gradually make their appearance, as represented in figures 16, 17, and 18 (fig. 16, living contracted muscle; D, fibrilla; A, dark transverse bands; B, globules; C, walls of the *kästchens*). (1.) When living muscle is thus treated, the first appearance is what seems like extreme contraction of the dark bands in certain limited but regularly longitudinal lines, as manifested by small particles of highly refractive material which present the appearance represented in fig. 18. But besides the small masses, it is to be noticed that there are slight lines passiug through the clear spaces, which we take to be the walls of the *kästchens* (fig. 16, C). When first seen they are extremely small and few in number, but gradually, as the current is prolonged, they not only increase in number but also in size. 2. When recently dead muscle is similarly treated, the lines which we have supposed to represent the limits of the *Kästchen* are not nearly so evident, the masses are larger and present a less globular outline, in fact, more resemble crystals in their appearance (fig. 17). When, however, a weak solution of HCl is added to the fibre, either living or dead, the masses at once assume a more strictly globular form.

By the alternate action of weak acid (HCl ·1 per cent.), and alkaline (soda ·1 per cent.) solutions, without the employment of the electric current, the muscular fibre may be made to contract and relax at pleasure, within certain limits. This subject will be brought up again.

On the addition to a living fibre of a 1 per cent. HCl solution, the globules will be seen to be alternating with the light bands. Sometimes they are very regularly arranged in longitudinal rows of considerable length. When they become first apparent they are as represented in figure 12, but when the acid has been permitted to act a little longer, the longitudinal striation becomes

more distinct, whilst the transverse is gradually lost (fig. 13.) If fibres thus treated be washed and allowed to remain in ·5 per cent. osmic acid solution for twenty-four hours, the outline of the globules will be rendered more distinct by darkening of the edges. The osmic acid does not make them opaque in the centre, but colours them slightly yellow. In those fibres where the globules are few in number and small in size (where the HCl solution has not acted sufficiently), the osmic acid seems to bring out the transverse striation more or less distinctly. By examining a large fibre, where the transverse striation is still apparent, with a magnifying power of 1000 diameters, it will be readily made out that the globules are intimately connected with the dark bands (fig. 19). In these fibres the size of the globules varies from ·00077 to ·001 mm. In a small or large fibre, where the striation is completely lost, they are much larger, being from two to three times the size of these, and are, when treated with osmic acid, no longer globular in shape, but oblong (fig. 20) A, prismatic B, or irregularly shaped C. They are not arranged in any definite manner, but appear to be dispersed irregularly within the sarcolemma. Again, if fibres in which there are only a few globules, and where the dark bands are not completely destroyed, be allowed to soak in absolute alcohol for sometime, it will be found that the globules have entirely disappeared, leaving the dark bands irregular and indented, and also that the contour of the unaltered dark bands is rendered more distinct.

We have shown the relationship of the globules to the transverse and longitudinal striation, and described the methods by which they may be produced; it still remains to be shown how they may be separated from the muscle, and as far as possible demonstrate their chemical composition.

Take two portions of living frog's muscle A and B, each weighing 13 grammes.

Divide A into not too small portions, as by over manipulation the life of the muscle will be destroyed; place the pieces in 200 c.c. of 1 per cent. HCl solution, and allow it to remain there for twenty-four hours. If a few of the fibres be now examined, the dark bands will be found to be replaced by the globules as above described. Now proceed to filter

off the fluid and wash the muscle with distilled water so as to remove any trace of hydrochloric acid or syntonin, tease out the fibres thoroughly and again wash. The muscular fibres should now be placed in 250 cc. of a mixture of equal parts of alcohol and ether, and allowed to remain there for twenty-four hours.

Supposing the fibres be now examined microscopically, the globules will be found to have entirely disappeared, and only occasional traces of transverse striation can be detected. We therefore conclude that the globules, in other words, the dark refractive material of the dark bands, are in solution in the alcohol and ether. After the muscle has been in the alcohol and ether for twenty-four hours, filter and wash the muscle with 100 c.c. of fresh alcohol and ether. If this filtrate be now evaporated to dryness, the residue redissolved in ether, filtered, evaporated, and weighed, it would be found to equal 0·068 grammes. To its chemical nature we shall refer hereafter.

B, take the other portion of muscle and reduce it in the same way, but instead of placing it first in HCl solution, put it at once into 150 cc., of equal parts of alcohol and ether. After allowing it to remain there for twenty-four hours, filter off the fluid, and placing the muscle in a mortar with broken glass, reduce it to a coarse powder. If a few of the fibres be now examined they will be found to be very much contracted, the transverse striation distinct and regular (12 = ·0172 mm.), the longitudinal striation very marked, and the fibres have a wavy appearance; no globules can be detected. The powdered muscle should now be washed with 100 cc. of alcohol and ether, which having been filtered is added to the other filtrate. Now proceed to evaporate, redissolve in ether, filter, and again evaporate, weigh the residue, which will be found to equal about ·015 grammes. The difference in the amount of material soluble in ether from 13 grammes of fresh muscle, and that from muscle which has been previously treated with a weak solution of HCl is 0·068 − 0·015 = 0·053 grammes, or in other words, the material of the globules produced from the broad dark bands by the action of HCl is equal to 0·053 grammes.

The residues from A and B are, on examination, found to consist of fatty matter, chiefly in the form of fatty acids, in the proportion of 33 parts of fatty acid to 1 of free fat in the former, and 15 to 1·8 in the latter. Therefore, the free fat in it is due to the

presence of that portion of fat which may be separated without previous treatment with HCl solution. Thus—

0·068 grammes of	A=0·0020	grammes	free	fat,
and 0·015 „	B=0·0018	„		„
	0·0002			

The difference is due probably to errors in the experiments, so that it may be assumed that the fatty matter composing the globules is made up of fatty acids. The exact nature of these fatty acids we have not yet fully determined, but it may be here stated that ·070 grammes of A requires ·060 grammes of caustic soda to neutralise it.

We have given above the quantitative analysis of Von Bibra, in which he shows that frog's muscle contains one part of fat in a thousand of fresh frog's muscle. Now this almost exactly agrees with what we have been able to separate by the direct action of ether (·13 : 1000 : : ·015 : 1·15), which we will in future designate *free fat*. He has, therefore, not known of the existence of fatty matter in a form in which it is not soluble by the direct action of ether, although it is present in a much greater proportion (13 : 1000 : : ·068 : 5·23), and may be dissolved out as we have shown by previously treating the muscle with weak HCl. To this fat, for the sake of description, not that the term is absolutely accurate, we will give the name *combined fat*.

We have now shown how this combined fat may be separated from the muscle direct; we will now see how it can be derived from muscle plasma. If living muscle of the lower extremities of the frog, from the vessels of which the blood has been carefully washed by injection of a dilute saline solution, be taken, and whilst frozen, freed as much as possible from nerves, vessels, &c., weighed, reduced to a small size, and powdered in a cooled mortar with broken glass, then mixed with four times its weight of snow containing 1 per cent. of chloride of sodium, and filtered at 0° C., under a pressure of 30 mm., through glass cotton, a fluid will be obtained of a dark straw-colour—muscle plasma.

This plasma at 0° C. is an almost clear straw-coloured fluid, and when neutral does not contain any deposit except perhaps a few minute fragments of glass. When, however, the tem-

perature is allowed to rise slightly, or if the plasma is rendered acid or alkaline, it no longer continues clear, but becoming cloudy throws down a deposit which collects slowly at the bottom of the vessel. Or again, if a drop of freshly-filtered plasma be examined by a power of 1000 diameters on a cooled slide, nothing of note will be detected; but if a drop of 1 per cent. HCl solution be now passed under the cover-glass, numerous minute fat globules become visible, associated with small flakes of albumen, in and around which the globules aggregate themselves. The deposit mentioned above will also be found to consist of these globules and flakes. The globules are exactly the same as those found in the muscle. They measure from ·00077 to ·0014 mm. in diameter. On more careful examination of the flakes they will be found to consist of a homogeneous material (fig. 21), containing the following bodies:—I. A very fine opaque granular material (A); II. Larger, globular, prismatic (B); or III. Irregular-shaped highly refractive bodies (C); the two latter show a beautiful play of red, blue, and green colours on alteration of the focus of the microscope.

Take two equal portions (25 cc.) C and D of the freshly prepared plasma at $-3°$ C.

To C add 50 cc. of 1 per cent. HCl at 3° C.
" D " 50 cc. " ether " "

Let C stand for half an hour, then add 50 cc. of ether, and allow it to stand for twelve hours, shaking the mixture repeatedly, after which evaporate to dryness. The whole of the albumen will be converted into syntonin by the HCl and the fat will be set free and dissolved out by the ether. It should now be purified and weighed, when it will be found to equal ·021 grammes.

D. After shaking it repeatedly it separates itself into two layers, the upper (ether) perfectly clear, whilst the lower has a milky appearance, and deposits a precipitate while standing. (1.) The upper stratum may now be separated at $-3°$ C., and evaporated to dryness, the residue dissolved in ether, filtered, and again evaporated and weighed. This, the free fat in the plasma, equals ·001 grammes. (2.) The lower layer should now be filtered, when a clear fluid will be obtained which does not give a precipitate with ether, but throws down a precipi-

tate on the addition of HCl solution, and the precipitate with ether will remain on the filter. If this precipitate be now treated with 20 per cent. HCl solution, it will dissolve after some time; shake this solution with ether, separate the ether, and evaporate it to dryness, redissolve the residue, filter, evaporate, and weigh, when the combined fat, equal to ·018 grammes, will be obtained. Therefore the combined fat ·018 grammes, plus the free fat ·001 grammes, = ·019 grammes from D, should be the same as what is got from C, namely, ·021 grammes. This little difference ·002 grammes is probably due to errors in the experiment D; seeing that the process is more complicated than that of C, it is not surprising that this minute difference should exist.

Freshly prepared plasma has the power of dissolving a certain quantity of this combined fatty matter at −3°C. If 50 cc. of plasma be taken and placed in a cooled vessel containing a given quantity of combined fat, which has been separated from muscle by one of the processes above described, it will be found that it has the power of taking up 0·918 grammes of the fat, in addition to what it contains naturally. Thus 50 cc. of plasma, which contains 0·020 grammes of combined fat, and say 0·001 grammes of free fat has the power of holding in solution ·018 grammes more, in all, ·039 grammes. This fat, however, like that of the muscle itself, separates readily when the temperature is raised slightly. To illustrate the bearing of the above observations another experiment is necessary. If a few fibres of the fully extended muscle of a frozen frog be examined, the necessary precautions having been taken to keep the temperature low, it will be found that the transverse striation is invisible so long as the temperature is below 3° C., but as soon as it rises slightly above that point, the transverse dark bars begin to appear, and contraction of the fibre gradually takes place. The dark transverse striation appears as broad bands, with a double contour, so as to give the appearance of two lines separated from each other by a clear space. As the temperature rises those two lines approach one another, and at the same time the band becomes more highly refractive. When the muscle is examined by means of the polarising microscope whilst in a state of perfect rest, that is to say, when no striation is visible, the whole of its substance is doubly refractive, but when the temperature has risen, the dark

transverse bars appeared, and contraction commenced, then only the space included between the two approaching dark lines possesses the property, the clear portions which remain being singly refractive.

We are now in a position to discuss the following points:—

I. *The absence of transverse striation during perfect rest; its gradual appearance, first as a broad dark transverse bar with a double contour, afterwards becoming narrow, the breadth being in an inverse ratio to the amount of contraction; also; that during a state of rest the whole fibre appears doubly refractive, and that only when contraction has taken place the alternating stripes possess the property of single refraction.*

We believe that during a state of perfect rest the *muskel-kästchens* are in the form of plain hollow cylinders, united at their bases more firmly than at their sides, the former being throughout the entire basal surface, whereas the binding of the elements laterally appears only at situations corresponding with the situation of the centre of the broad dark bands (fig. 22, A). This idea is supported by the fact that in bundles of living muscular fibre it is very easy to separate the fibrillæ from one another, but it is impossible to procure an analysis of the bands, *i.e.*, to break the junction of the elements transversely. These cylinders contain a fluid—muscle plasma, which during a state of rest holds the whole of its combined fat in complete solution, so that the whole of the contents of the *kästchens* or of the fibre possess the properties of double refraction; but, when either the electrical or chemical condition of the plasma is altered, first the plasma at the sides of the basal membranes, then progressively towards the centre, precipitates its fat, and as the fat is thus precipitated it collects itself in the form of a flattened disc at the centre of the cylinder. Moreover, at the beginning of this process there is a tendency to repulsion of the precipitated fat from the sides of the cylinder, which is, however, easily overcome, so that the so-called prisms assume the form of an ellipted cylinder. The remaining plasma, which is thus freed from its fat, *i.e.*, the light bands, will be only singly refractive. This idea is illustrated in figure 22. Section 1 represents the cylinder in a state of perfect rest, as is seen in frozen muscle.

B, basal membrane; *s*, lateral walls of cylinder; *k*, plasma containing the whole of the combined fat in solution, there is, therefore, no broad dark band. Sections 2, 3, 4, 5, show the state of matters during contraction, and will be referred to further on.

The fatty matter is not, strictly speaking, in a state of chemical combination with the muscle plasma when the muscle is in a state of rest but merely held in solution. The conditions which lead to the precipitation of the fat from the plasma, either while the latter is a constituent of the living fibre or after it has been separated from the muscle at a low temperature, are identical; thus we find elevation of temperature above 3° C. causes the fat to separate from the plasma, it likewise produces the dark bands in the fibre, together with contraction of the muscle. The same may be said in respect to the action of very weak acids, alkalies, and electricity. These agents act as stimuli when applied to muscle, by virtue of their power of causing the fatty matter held in solution to be precipitated, which, as will be pointed out further on, produces, by its concentration towards the centre of the cylinders, contraction. The majority of solutions, even distilled water, causes muscle which is at rest to undergo contraction. A solution of ·5 per cent. of chloride of sodium is one of a few indifferent fluids. The same is true in relation to the solution of fat in the free plasma; the least change in its thermal condition, the addition of a very dilute acid or alkali, or the application of an electric current tends to cause the precipitation of the fat in the form of small globules, as has been already described, so that it is often with difficulty that plasma, perfectly free from these globules, can be obtained.

In connection with the exchanges of matter of muscle during a state of action it may be mentioned that the quantity of free fat is increased, and that of combined fat diminished during a state of activity: that is to say, a certain portion of the fatty matter held in solution by the plasma is set free during a state of action. If a muscle which has been tetanized be examined, a large number of the globules may be detected, and the fibres do not respond so readily to the action of stimuli, a result, we believe, of the deficiency in the quantity of combined fat,

whereas in a muscle which has been in a state of rest for some time very few of the globules are to be seen, the quantity of combined fat is large, and as a result the irritability is well marked. This liberation of the fat, held in solution by the plasma, has given rise to the idea (J. Ranke) that muscle during activity produces fat, whereas it only frees it from its connection with the plasma, and places it in circumstances so that it is able to be taken up by ether. Why ether is unable to separate the fatty matter held in solution by the plasma is easily explained, when one remembers that the muscle plasma is to a considerable extent coagulable by ether, it can be readily seen that the ether in reality never reaches the fat, it being enclosed in a state of molecular division, in a shell of coagulated albumen.

Healthy muscle in a state of rest contains a store of this fatty matter in solution in the muscle plasma; during muscular exertion it is precipitated within the muscle-cylinder, most of this fat is again taken up by the plasma, whilst a certain quantity is so altered that it remains as free fat, which either becomes absorbed and carried into the circulation as such, or is previously altered in its chemical composition.

The blood effects the recovery of the muscle in this respect, by supplying it with fresh fatty matter, or matter which is convertible into fat, and at the same time it removes the waste products.[1] If muscular exertion is excessive, then the supply of fresh material cannot keep pace with the expenditure, and, as pointed out above in reference to muscle that has been tetanized, the amount of the fat is increased, whilst the combined fat is diminished, and as a consequence the muscle can only be stimulated to contraction with difficulty.

It may be of interest to mention that we have succeeded in making muscular fibres of a frog, which had been preserved in a moist chamber, contract under the microscope, by the addition of a weak acid or alkaline solution, as long as fifty or seventy hours after the death of the animal, many hours previous to which the muscle had ceased to respond to electric or mechanical stimuli.

[1] Blood corpuscles of the frog contain *combined fat*, which may be demonstrated in the same way as that of muscle.

II. *The diminution of the longitudinal as associated with increase in the transverse measurement of the muscle, without any loss of volume.*

This is, doubtless, a result of contraction of the cylinders in their longitudinal and expansion in their transverse axis. How, then, is this brought about? The theory of the changes we suppose to take place is illustrated in figure 22, which is intended to represent a fibrilla in section during the various stages of contraction. The uppermost division (1) shows the condition of matters when the muscle is in a state of perfect rest. B, The basal membrane, or thin dark lines, S the sides of the cylinder, and K the uniform doubly refracting contents. The broad transverse band is not visible, because the whole of the fatty matter is in complete solution in the muscle plasma. In the following division (2), the fat has been precipitated to a slight extent, and the lines F, which give rise to the double contour, are beginning to recede from the basal membrane towards the centre of the cylinder, leaving the remaining plasma (or more correctly speaking *muskel-kästchen* fluid), free from fat, and so depriving it of its power of double refraction. By reason of the tendency of the fatty matter to accumulate towards the centre of the cylinder, the walls are bulged out laterally so as to give the fibrilla a varicose appearance, causing shortening of the cylinder in its longitudinal, and lengthening in its transverse axis. If this change be now supposed to occur throughout all the cylinders of the muscle, it is evident that the muscle will contract and at the same time increase in its transverse measurement without any actual diminution in volume.

III. *The absence of longitudinal striation in a state of rest, and its appearance during contraction of the muscle.*

If we suppose a number of cylinders in a state of rest, as represented in figure 22, section 1, placed side by side, the cylinders being plain the sides will be in close apposition to one another, and the spaces separating them will be at a minimum, so the longitudinal striation will not become evident; but if, in contradistinction to this, we place the cylinders of a more or less contracted muscle, as represented in sections 2, 3, 4, or 5, alongside one another, it will be seen that the spaces separating

the portion corresponding to the position of the basal line (*o*) are greater or less in proportion to the amount of contraction. This is exactly what is seen in muscle when examined under the microscope, the greater the amount of contraction the more distinct is the longitudinal striation, and when the muscle is in a state of rest it is invisible. We have still to explain—

IV. *The appearance of the thin dark lines or basal membranes in relaxed muscle, and in muscle that is stretched and contracted, and their absence when muscle is shortened and contracted.*

Again refer to fig. 22. When the cylinders are, as represented in section 1, the basal membrane (B) will not be in a state of tension, but rather relaxed, and may be thrown into slight folds, and so rendered more evident, but when *shortening and contraction* takes place there will be bulging of the centre of the cylinder and the basal membrane will become stretched out, the folds disappear, and so the impediment to light passing through this portion of the fibrilla diminished, and therefore less evident to the eye of the observer. If, however, the *contraction* be *not* associated with *shortening* in the long axis of the fibre the cylinder will assume a shape as represented in figure 23, the walls being bulged out at points corresponding to the position of the broad dark bands, and collapsed at other parts, so that there is no reason why the thin basal membranes should disappear; seeing that they are not subjected to tension, the relaxed and folded condition remains.

Before concluding, we have but a remark to make in connection with a morbid condition of striated muscle, fatty degeneration in its early stages, as distinguished from fatty infiltration. A muscular fibre which has undergone fatty degeneration presents very much the same appearance as healthy fibre which has been subjected to the action of dilute hydrochloric acid or weak alkalies, the only difference being that the fat globules are usually of a slightly larger size, and there may be a slight increase in the corpuscular elements of the intersticial tissue. The globules are arranged in the same manner and bear the same relations to the histological elements in both cases. Fatty degeneration, or an appearance similar to it, may be induced in

the muscle of the frog through deterioration of the quality of the blood; thus if a frog be bled and the blood replaced by a mixture of 5 per cent. salt solution and peptones, the frog kept alive for a few days, and the muscles then examined, a result is produced exactly similar to what is seen in muscle during the early stages of fatty degeneration.

NOTE OF A CASE OF ARTICULATION BETWEEN TWO RIBS. By J. H. Scott, M.D., *Professor of Anatomy, University of Otago.*

This condition was found in a male body which was dissected last winter in the Practical Anatomy Rooms of the Otago University.

The 5th and 6th ribs of the left side articulated with each other by means of two bony processes, which projected from the adjacent borders of their shafts about half way between the angle and the anterior end.

These processes were somewhat flattened from without, and expanded as they approached each other. The lower, which was the larger, was slightly cupped above, to receive the convex head of the upper. The intercostal groove passed external to the neck of the upper process.

There was a complete capsular ligament, and several fibrous bands passed between the opposing surfaces in the interior of the joint.

A synovial membrane lined the capsule, and invested the inter-articular bands.

NOTE TO PROFESSOR SCOTT'S PAPER. By Professor Turner.

In the fourth volume of this *Journal*, p. 245, Dr J. A. Campbell gave an account of a case in which there was union between the 1st and 2d ribs both on the right and left sides, between the 8th and 7th left ribs, the 9th and 10th left ribs, and the 4th and 5th right ribs. The union was by a growth of bone across the intercostal space from one rib to the other. Sandifort, in the *Museum Anatomicum*, Plates XLVII. and XLVIII., figures several cases of ribs united together by bridges of bone, and in figs. 6 and 7 of Plate XLVII. he figures single ribs with a bony growth projecting from the upper border of each, similar to that recorded by Dr Scott in the lower of the two ribs in his specimen, and which had in all probability articulated with the rib situated immediately above in the series.

A few years ago I obtained from a subject in my dissecting-room a specimen not unlike Dr Scott's, in which a bar of bone, $1\frac{2}{10}$ths inches in antero-posterior breadth, projected from the upper border of the 2d right rib across the 1st intercostal space, and articulated by a movable joint with the outer border of the somewhat broadened shaft of the 1st rib.

ADDITIONAL NOTE ON THE ORGAN OF BOJANUS. By MARCUS M. HARTOG, M.A., B.Sc., F.L.S., *Assistant-Lecturer and Demonstrator in Biology, Owens College, Manchester.*

OWING to my receiving the proof of my Note on *Anodon* in the last number of this *Journal* during the vacation, a delay occurred in returning the proof, which resulted in the note being printed without my corrections, which I now proceed to give.

The external orifice of the kidney is nearly horizontal, or parallel to the long axis of the animal. Not only can we judge *a priori* that the ciliary current through this organ "must be outwards," but I have determined it to be so by microscopic examination.

After writing the note, my attention was directed to Professor Sabatier's paper on *Mytilus* (in *Ann. Sc. Nat.* ser. vi. vol. v.). He finds the opening from the pericardium guarded by a valve, so that an injection can pass thence into the kidney, but not from the kidney into the pericardium. I now find the same arrangement in *Anodon.* The single aquiferous pore in the foot of *Mytilus* would play the same part as I ascribed to the multiple pores in *Anodon.* Professor Sabatier's remarks tend, on the whole, in the same direction as mine; and, indeed, he has the priority in disproving the alleged mixture of blood and water in the pericardium, by means of its renal apertures. However, my work was independent, and contains some points not brought in by him. The existence of a stream in the contrary sense in any of the mollusca must now be demonstrated to shake our present firm standpoint.

A TWO-HEADED SARTORIUS. By G. S. BROOK, *Assistant Demonstrator of Anatomy, University of Edinburgh.*

IN a dissection of Scarpa's triangle, made in the University Anatomy Rooms, an anomalous muscular slip, fully a quarter of an inch in thickness, was observed running down the centre of the space close to the outer side of the femoral artery, and blending with the main fibres of the sartorius in their lower third. It was connected above with a distinct flattened tendon nearly a quarter of an inch in diameter, which on being traced upwards was found to take its rise from the ilio-pectineal line external to the pectineus muscle, between it and the psoas. From this attachment the narrow tendon passed downwards and outwards over the psoas muscle behind the internal circumflex and femoral vessels, to emerge at the outer side of the latter just below and in front of the origin of the profunda artery, and to terminate in a fleshy belly having the course and destination already described. The tendon was about three inches long. The normal origin of the muscle, which must in this case be called the outer head, had the usual origin and course. No similar variety in this muscle has been collected by Professor Macalister from the writings of anatomists in his valuable Catalogue of Muscular Anomalies.

NOTE ON ETHIDENE. By Professor M'KENDRICK.

IN the last number of this *Journal* there appeared a report from the Committee on Anæsthetics of the British Medical Association, chiefly relating to the influence on blood-pressure of chloroform, ethidene, and ether. The present number contains a plate, giving portions of kymographic tracings (Plate XXII.). The previous history of ethidene as an anæsthetic appears to be as follows:—

Ethidene was first employed as an anæsthetic by Dr Snow of London. He administered it in fifteen cases with good results. See Snow *On Chloroform*, &c., last paper, published in 1858. In 1870 it was used by Liebreich and Langenbeck in Berlin (*Berlin. Klin. Wochenschrift*, Nos. 31 and 33, 1870, p. 401). In 1871 two papers appeared: one by Sauer, in the *Pharm. Centralb.* 14, p. 140, and the other by Steffen in *Deutsch. Klinik*, 44, p. 398. Sauer mentions one case of death in a patient suffering from heart disease. In thirty-three cases, two vomited and two suffered from nausea and headache. In 1872 Steffen published another paper in the same journal (p. 358), in which he gives details regarding twenty cases, and he states that the results were satisfactory. See also *Jahresb. der Medicin*, 1870, 1871, and 1872, where abstracts are given. It is worthy of note, however, that Snow, whose work in connection with anæsthetics is well known and much appreciated, was the first to use the substance. When he obtained it, it had been employed in Paris as an application to joints in rheumatism. What led him to give it a trial as an anæsthetic does not appear; but he states that the difficulty in obtaining it pure may prevent its general use. That difficulty chemists have now removed, and there is little doubt that, if required, ethidene may be made in a state of purity and at a moderate cost.

Notice of New Book.

ENTWICKLUNGSGESCHICHTE DES MENSCHEN UND DER HÖHEREN THIERE. Von ALBERT KÖLLIKER, Leipzig, 1879.

ON the appearance of the first part of Professor Kölliker's work, we wrote a review of it, which was published in the tenth volume of this journal. The complete work is now before the world, and constitutes a volume of over a thousand pages, illustrated by six hundred and six woodcuts. The contents of the work are strictly defined in the title. It contains an account of the embryology of man, and of the higher animals, and a very scanty notice indeed is taken of the lower vertebrate forms. It may well be conceived that the limited subject of which the work treats, receives in the thousand pages devoted to it an almost exhaustive treatment. Professor Kölliker's treatise is, in fact, no text-book for students, but a real monograph, and, as such we presumed, it is to be criticised. Were it not for this consideration we should be inclined to say that the literature of the subject is treated of at too great a length. We ourselves, and we have no doubt that other embryologists have our views, do not feel in the least inclined to complain of this, but are, on the contrary, very grateful to Professor Kölliker for the amount of labour he thereby saves us; but we fancy that should the work fall into the hands of beginners, they would feel very much overwhelmed by the variety of opinions put forward by eminent embryologists, and feel very much inclined to doubt whether there is anything in embryology which can be regarded as established.

As we have already spoken of the contents of the first part of the work in our previous review, we shall mainly confine our observations to the second part. This part deals entirely of the system of organs. It commences with an account of the development of the osseous system. With reference to this subject, we may remark that, in our opinion, Professor Kölliker, in common with his countrymen generally, hardly does justice to the researches of Professor Parker, and we are inclined to think that the section of his work devoted to the development of the skull would have been considerably improved had he studied Parker's paper on the development of the skull of the pig, which is not even quoted in the literature of the subject.

Professor Kölliker adopts, with reference to the notochord, Dursy's view—that it has no special sheath; a view which we cannot share.

The next section of the work is devoted to the nervous system. It contains a very full and valuable account of the development of the brain.

The development of the nerves as outgrowths from the central nervous system is recognised, and figures showing this are given.

With reference to the olfactory nerves, Kölliker opposes the observations of Marshall, according to which these nerves arise previously to the formation of the olfactory lobes, mainly on the ground of Remek's statement that the olfactory lobes appear on the third day at a period before Marshall finds the olfactory nerves. This is, however, an error. Remek makes the statement attributed to him, but corrects it subsequently in a note on page 74 of his Untersuchungen. His uncorrected statement on this subject has, unfortunately, been quoted not only by Kölliker, but by other authors, including Dr Foster and myself.

The chapters devoted to the sense organs are admirable expositions of the present state of our knowledge about these organs. With reference to the eye, many of the views brought forward by Keggler in his valuable memoir are adopted, but here, as in every other case, Professor Kölliker has thoroughly reinvestigated the whole subject for himself.

The chapters on the sense organs are followed by a chapter on the epidermis, which is again succeeded by one on the muscular system. Professor Kölliker is of opinion that the data are not yet to hand for a satisfactory treatment of the comparative development of the muscles.

There is nothing very new in the chapters on the alimentary tract and the vascular system, which follow that of the muscular system.

The work closes with a chapter on the urino-genital organs. We confess that we should have been glad to have seen this chapter expanded to some extent. The development of the permanent kidneys is dealt with extremely briefly, and the interesting questions with reference to their homology are dismissed with the statement that they lie outside the scope of the treatise.

The development of the ova and Graafian follicles is treated of at some length. The views on this subject, which the author announced in the "Proceedings of the Medico-Physical Society at Würzburg," are here fully worked out, and figures are given in support of them. Professor Kölliker holds that the primitive ova are derived from the germinal epithelium, but that the epithelium of the follicles originates from peculiar cords in the stroma of the ovary, which we have elsewhere spoken of as tubuliferous tissue. We have already expressed our dissent from the above view in so far as it concerns the follicular epithelium. A comparative study of this subject shows in the clearest manner possible that in many forms, notably the elasmobranchii, the follicular epithelium is derived from the cells of the germinal epithelium. We believe that no one who is familiar with the mode of formation of the follicular epithelium in the lower vertebrate forms will have any difficulty in recognising the same mode of formation in mammalia; and we consider it somewhat unfortunate that several of those who have recently been engaged in working on this subject should have confined their attention to a group in which the appearances are admitted on all hands to be so difficult of interpretation.

Viewing the work as a whole, it forms a splendid monument of learning and research, and will, we are sure, add greatly even to the reputation of the distinguished Professor of Anatomy at Würzburg. The only general criticism we feel inclined to make is that the morphological importance of the facts narrated is hardly sufficiently insisted on. The illustrations are numerous, and are executed in the best style of German scientific wood-engraving.

F. M. BALFOUR.

EXPLANATION OF PLATE XXII.

In illustration of the Report on Anæsthetics, page 387.

Some of the tracings referred to in the text are here reproduced, it being understood that in the original the tracings are white on black instead of black on white. The basement line represents the point at which the needle was when the mercury in the two limbs of the manometer was level. According to the pressure, the mercury is pressed down in the one limb and raised in the other, the tracing giving the latter. As the actual pressure equals the weight of the column of mercury raised, this will be represented by the difference in the levels in the two limbs, and will be double the distance from the basement line to the tracing. The tracings are to be read from left to right.

A. Represents the occurrence mentioned in the text, in which, while a dog was recovering from chloroform, a sudden fall of pressure occurred, with great reduction in the frequency of the heart's contractions. There is a gradual recovery, with striking inequalities of pressure corresponding with respiratory movements.

B. Another sudden fall of pressure and retardation of the heart's contractions occurring seventy seconds after the removal of the chloroform, and when the pressure had returned nearly to the normal.

C. The arterial pressure in a dog under the influence of chloroform. There is a progressive but somewhat irregular reduction of pressure, ending in a stoppage of the heart, while respiration continues. There is an imperfect recovery of the heart, the contractions barely causing the pressure to reach the basement line. Beneath this tracing are copies of the markings made with the chronograph, half seconds being registered. The markings used to indicate the administration or leaving off of an agent are also reproduced.

D. The arterial pressure in a dog under the influence of ethidene. There is a perfectly regular and gradual reduction in the pressure, the respiratory variations being preserved.

E. This is a continuation of D, after an interval. Ethidene has been given all the time, and the illustration begins at the point where the pressure is lowest. The pressure is now beginning to rise, the ethidene being still continued.

F. The arterial pressure in a dog under the influence of ether. No effect on the pressure is produced, and the respiratory variations are perfectly preserved.

G and H show the variations in pressure produced in rabbits by the administration of chloroform, the animals being at this time imperfectly under its influence. These variations are presumed to be reflex.

J and H show the exaggerated respiratory variations produced while artificial respiration was being carried out. It is to be understood that the animals made synchronous respiratory efforts. The arrangement for artificial respiration not only blew air into the lungs, but sucked it out.

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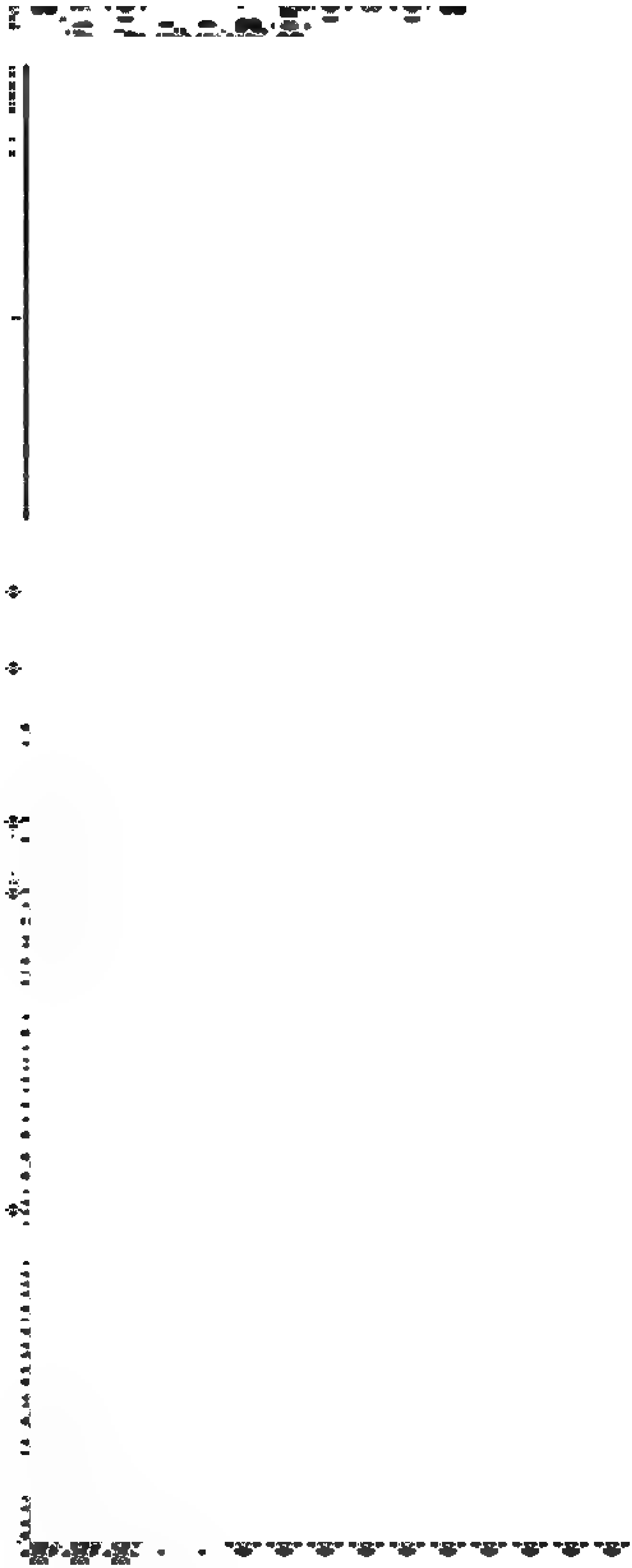

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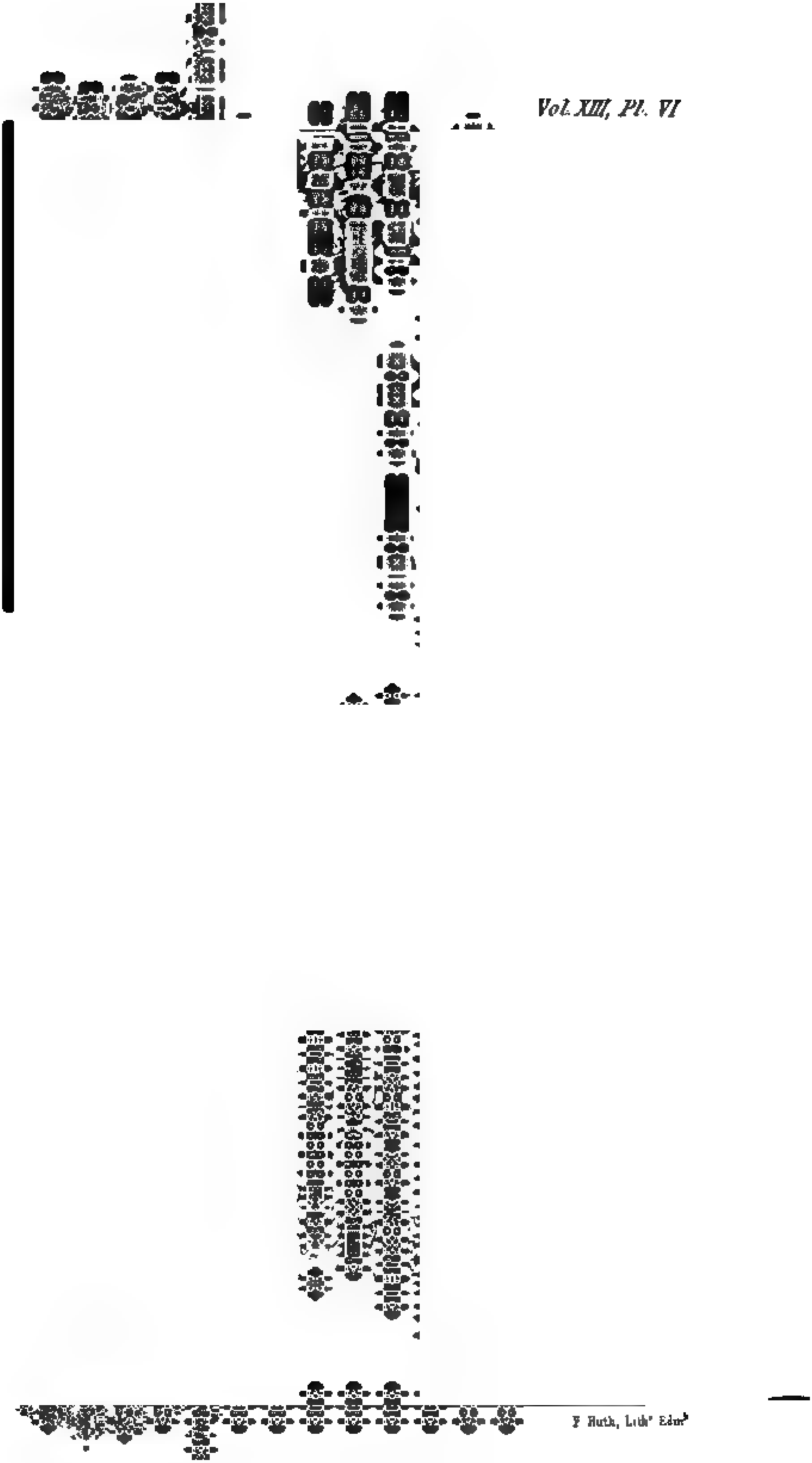

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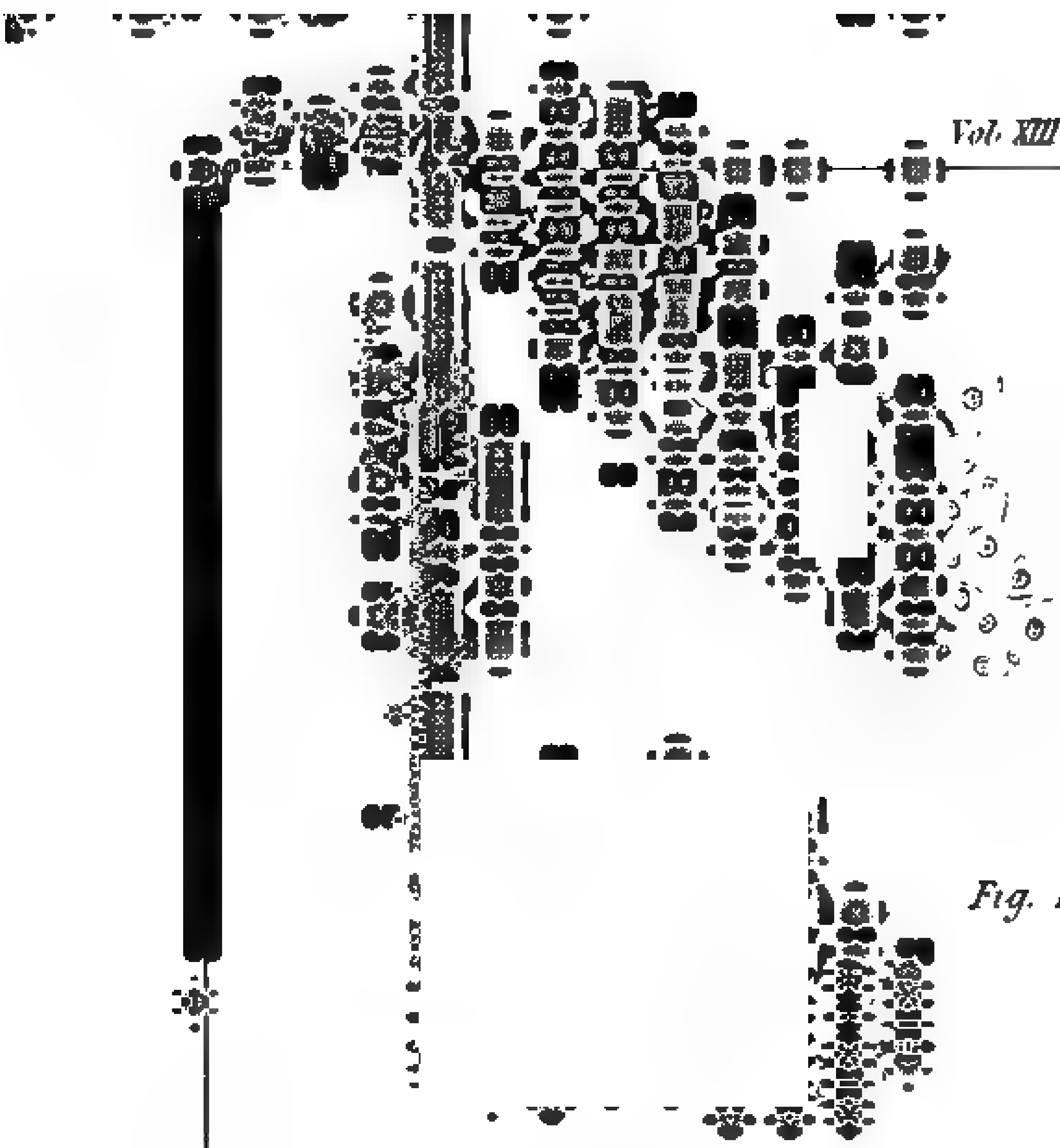

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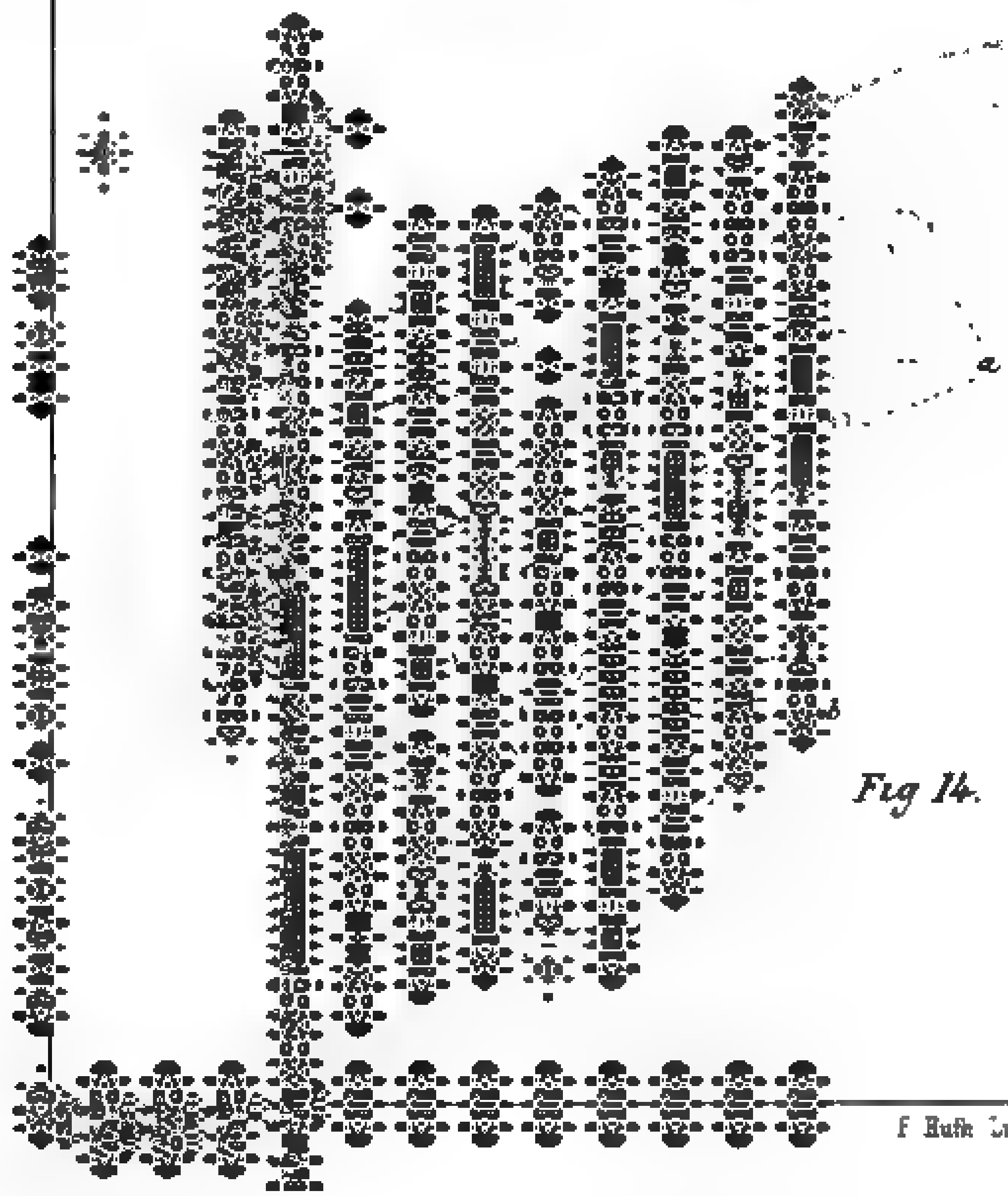

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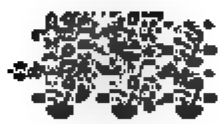

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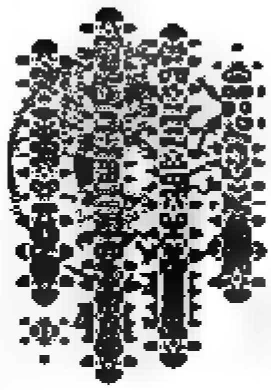

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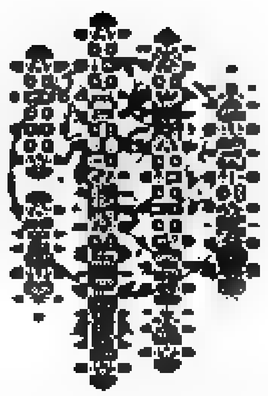

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[*To face Plate IX.*]

Explanation of Plate IX.

Fig. 1 × 300. Epithelium, primary cells, at a very early stage. (1) First or innermost cell; (2) second or rod-cell; (3, 4, and 5) outer cells.

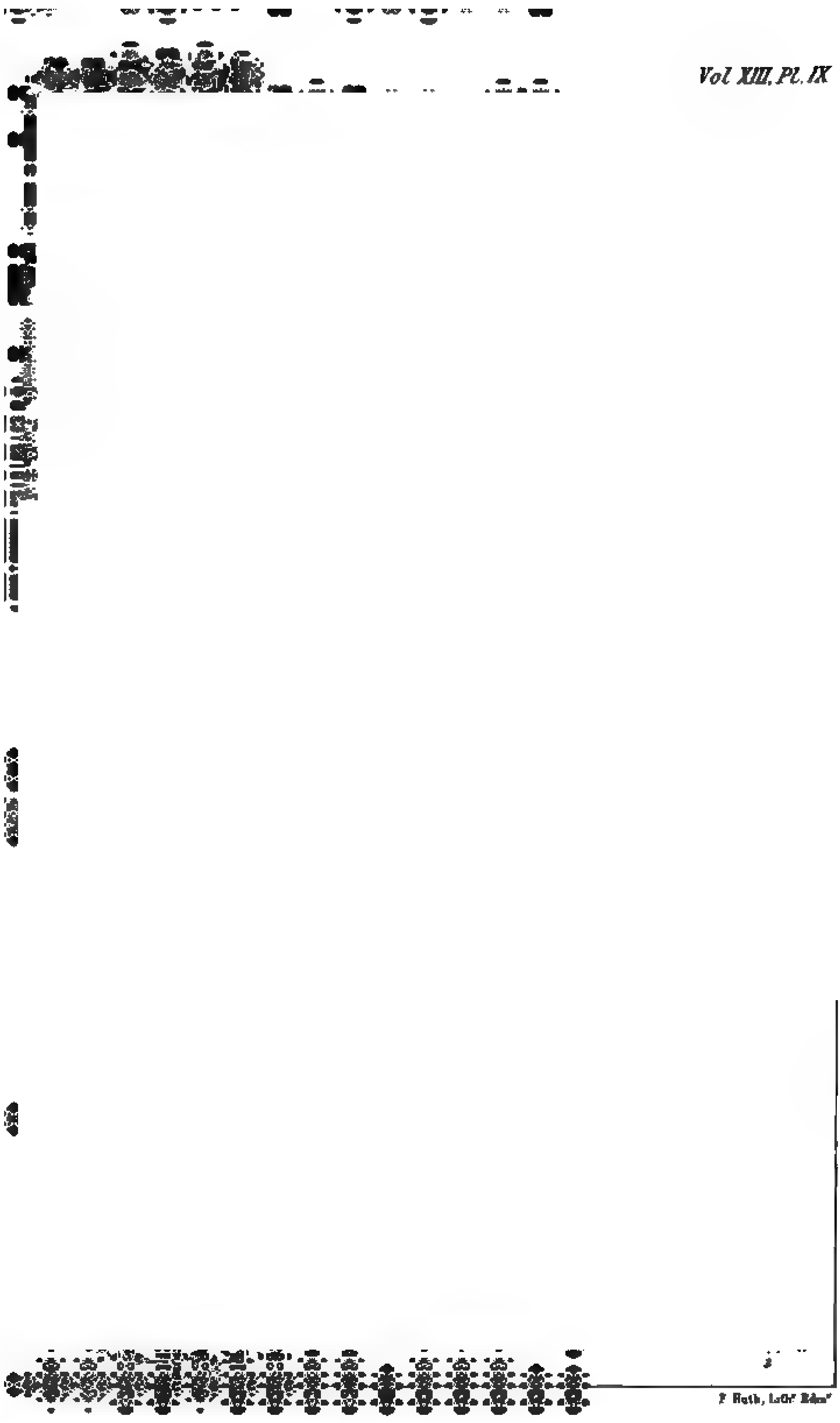
Fig. 2 × 300. A later stage. (2) Triangular rod-cell; (1, 3, 4, and 5) dividing to form upper and lower cells.

Fig. 3 × 300. A further advanced stage. (2) Rod-cell showing rudimentary rods and the vacuole.

Fig. 4 × 300. At birth, taken from lower part of the spiral.
These four figures are from the kitten.

Fig. 5. Diagrammatic section of lamina spiralis membranacea,—

1. Lamina spiralis ossea; (*a*) nerve.
2. Membrana basilaris.
3. Ligamentum cochleæ; (*b*) stria vascularis.
4. Sulcus spiralis; (*c*) upper, (*d*) lower lip.
5. Membrana tectoria.
6. Hair cells; (*e*) inner, (*f*) outer.
7. Membrana reticularis.
8. Supporting cells.
9. Rods; (*g*) inner, (*h*) outer.
10. Spiral tunnel.



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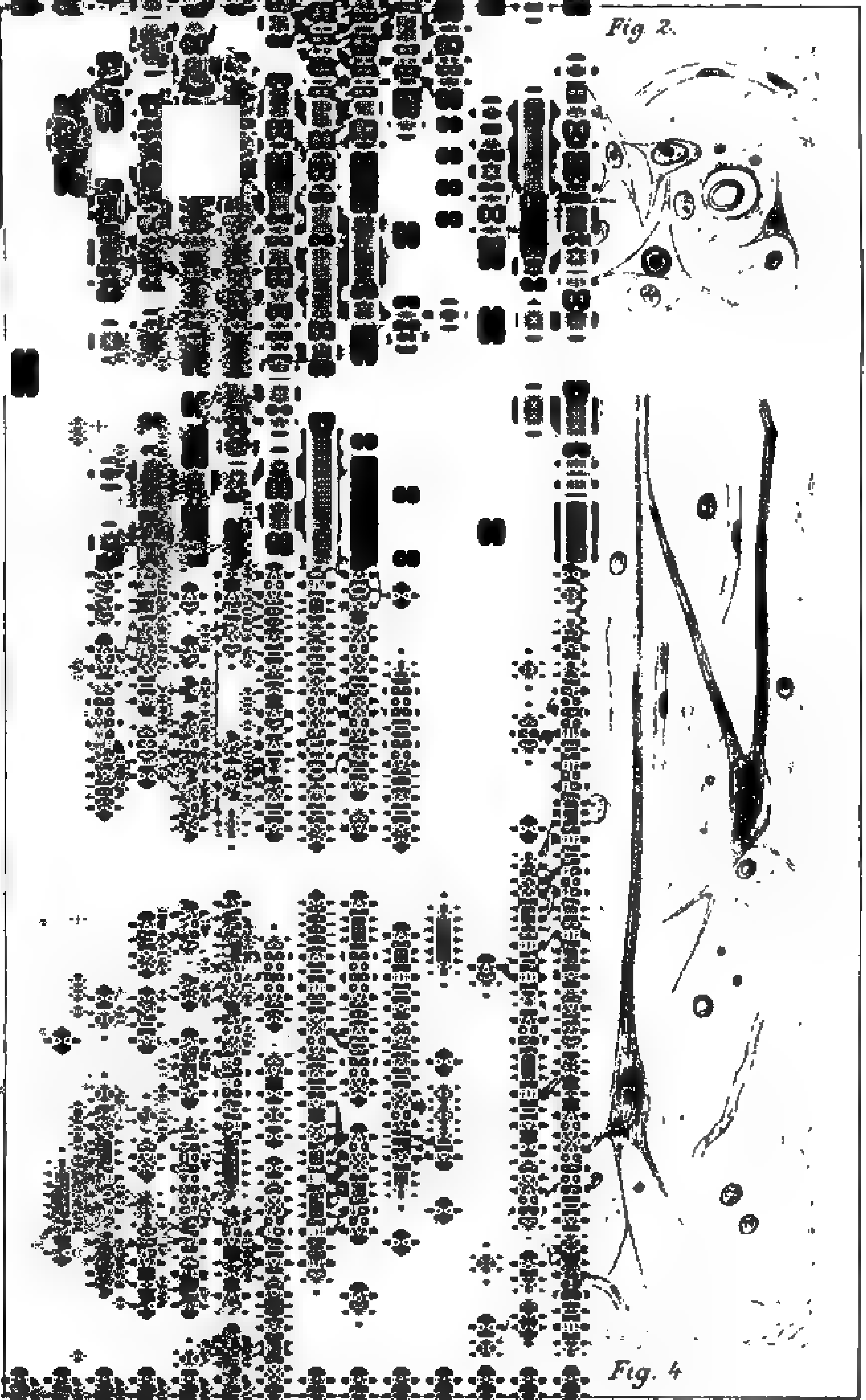

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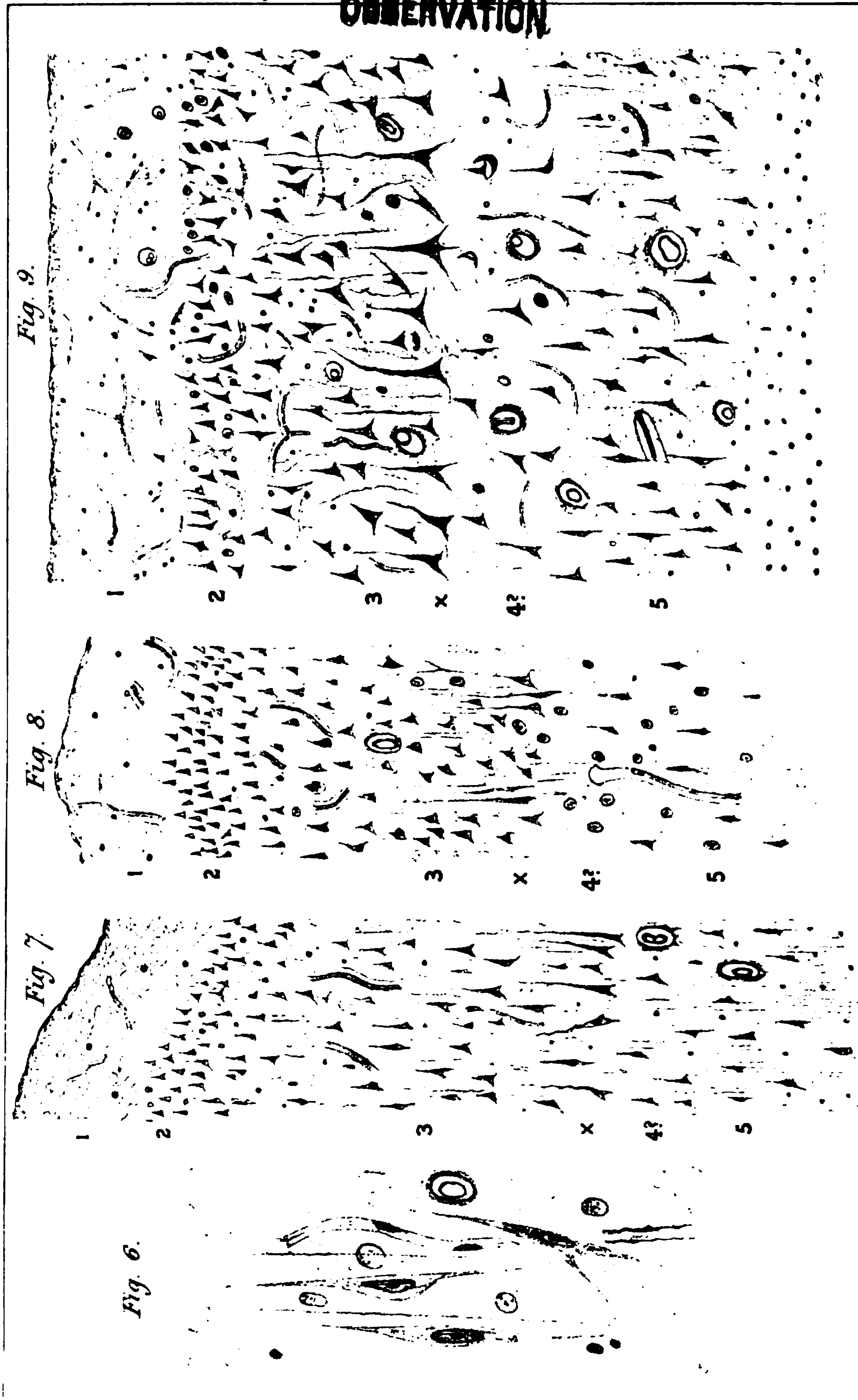

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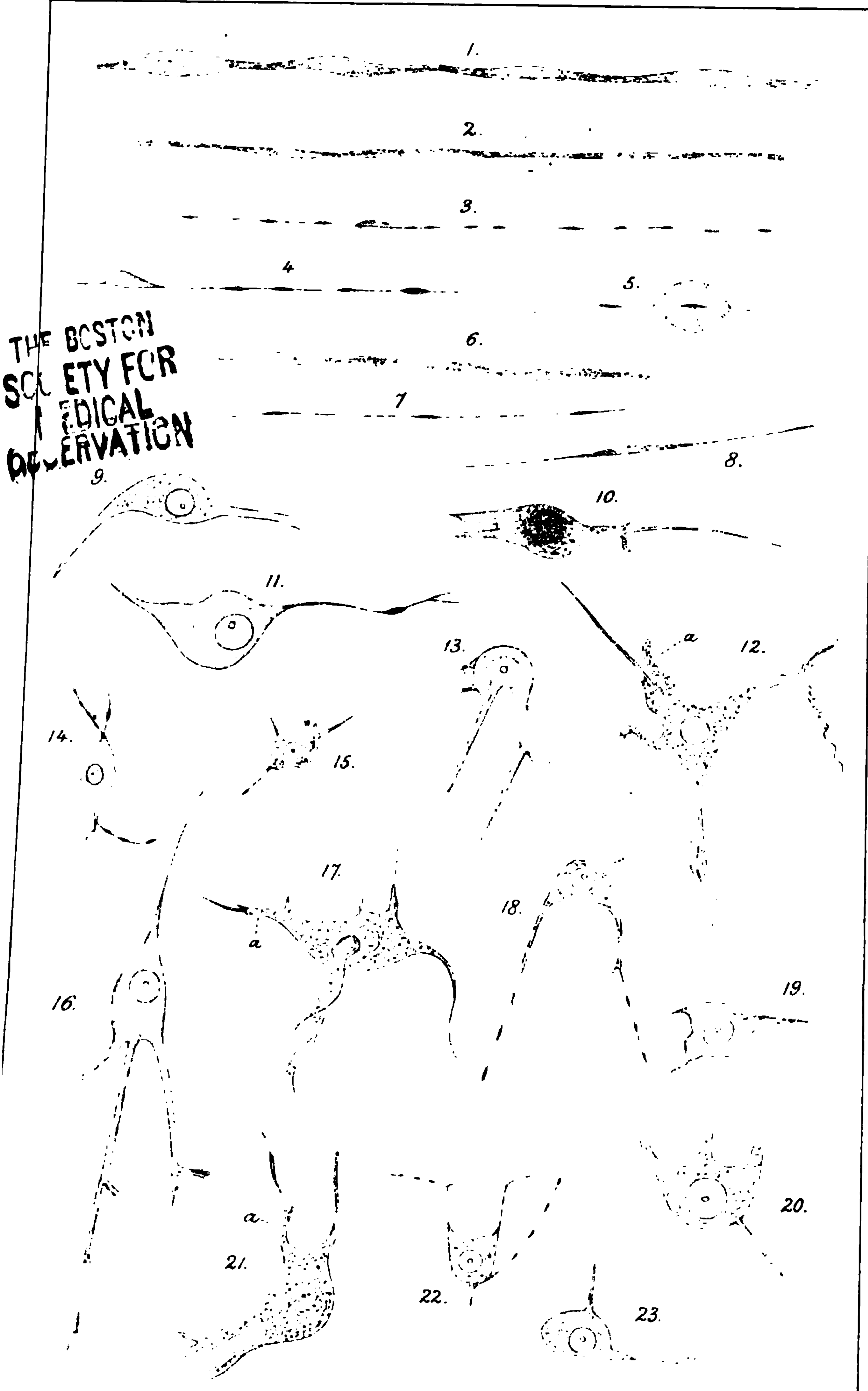

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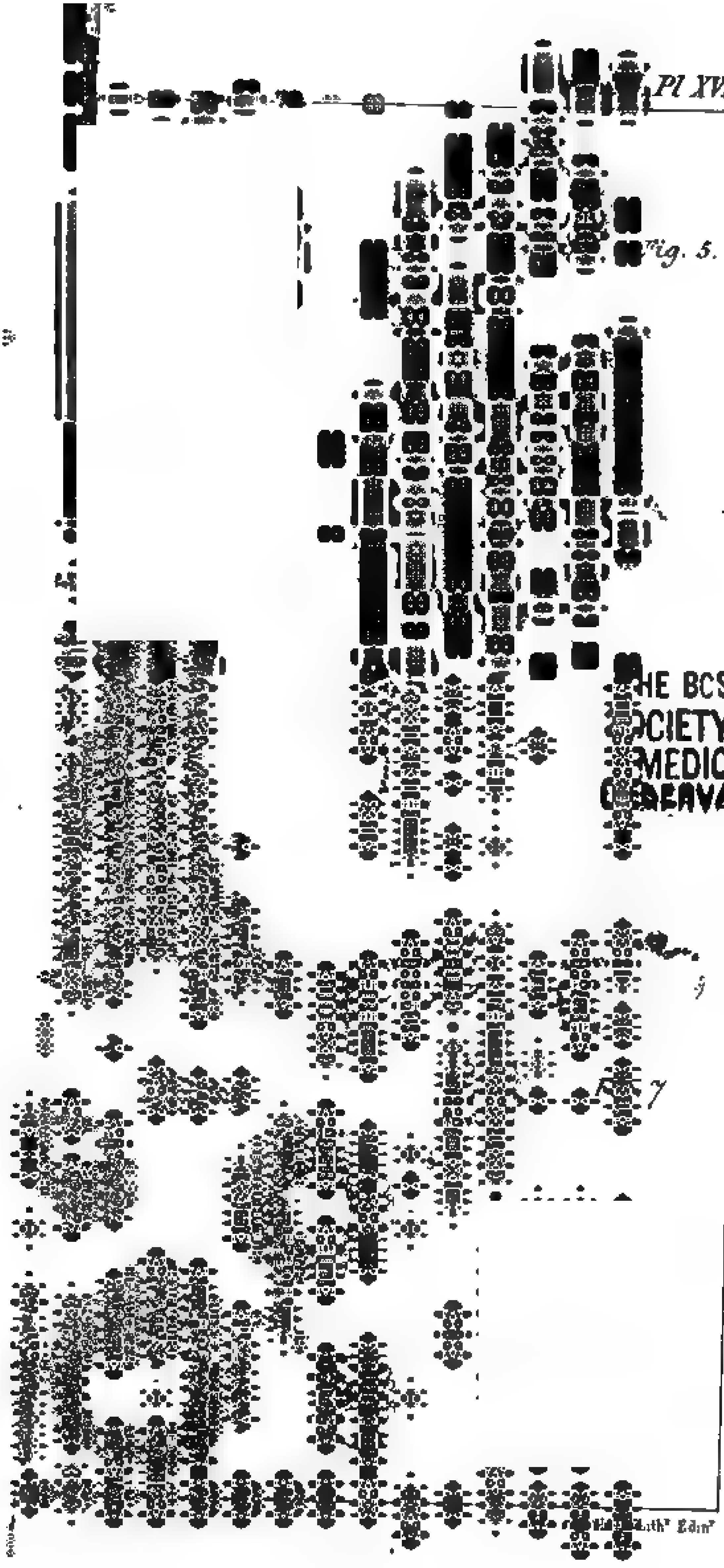

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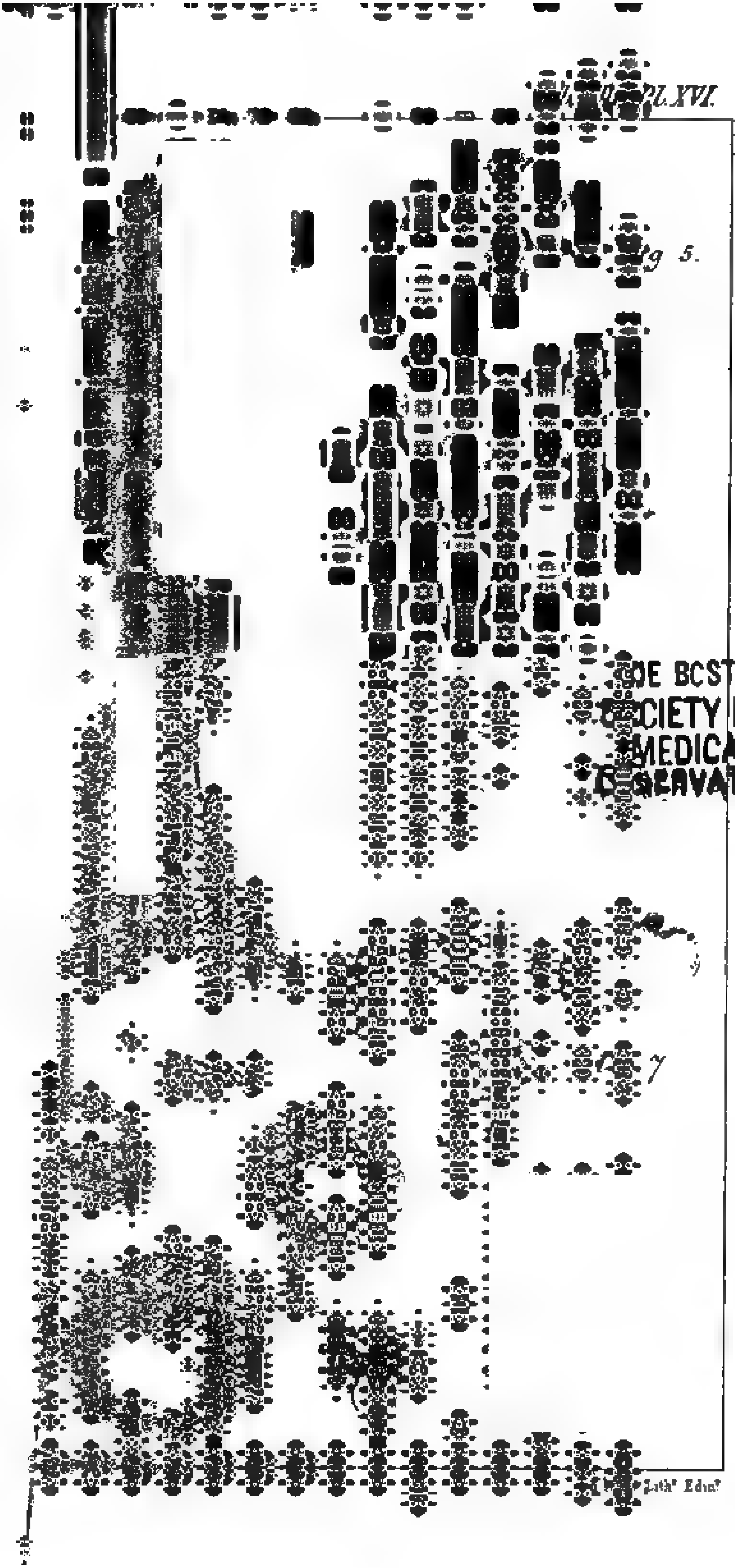

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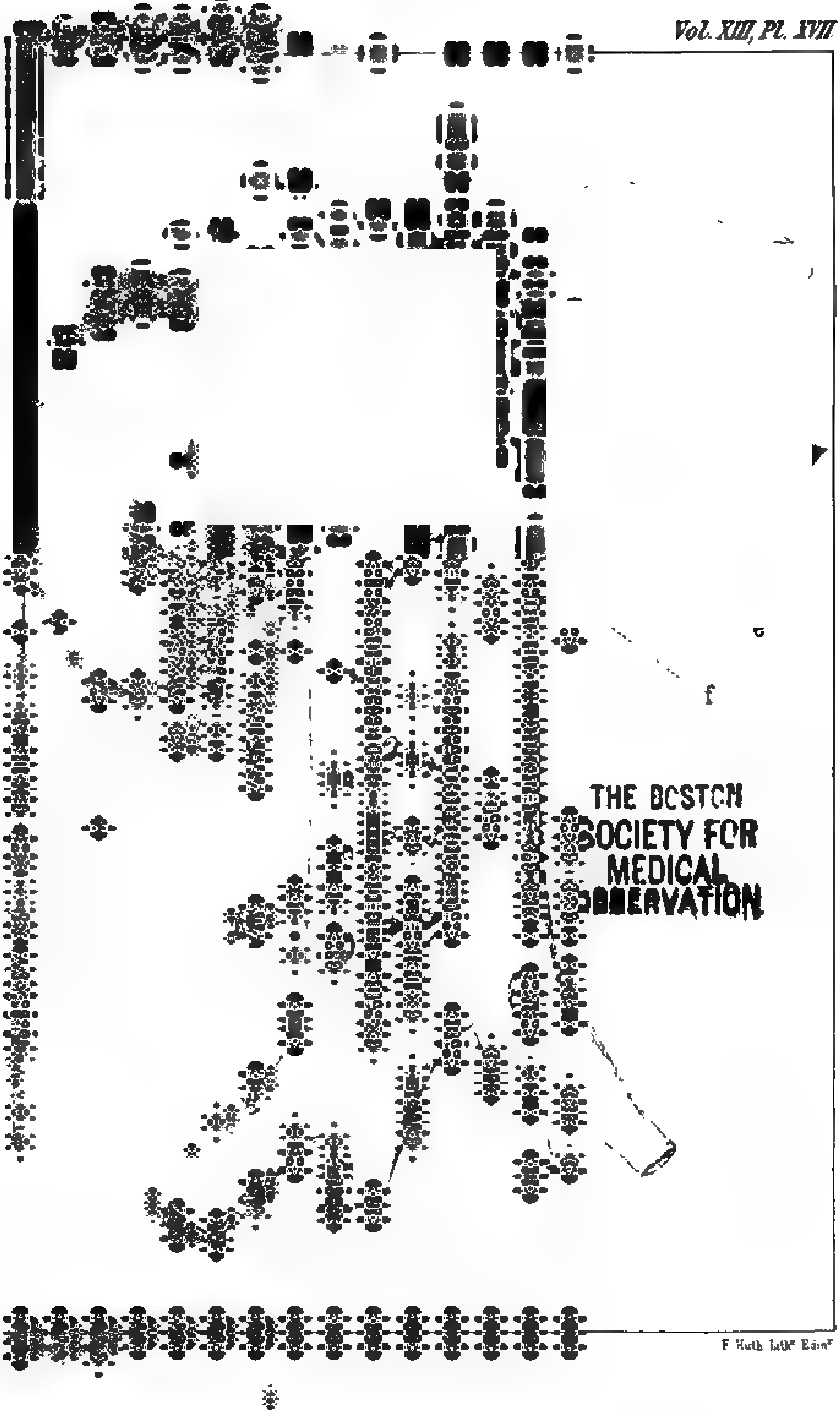

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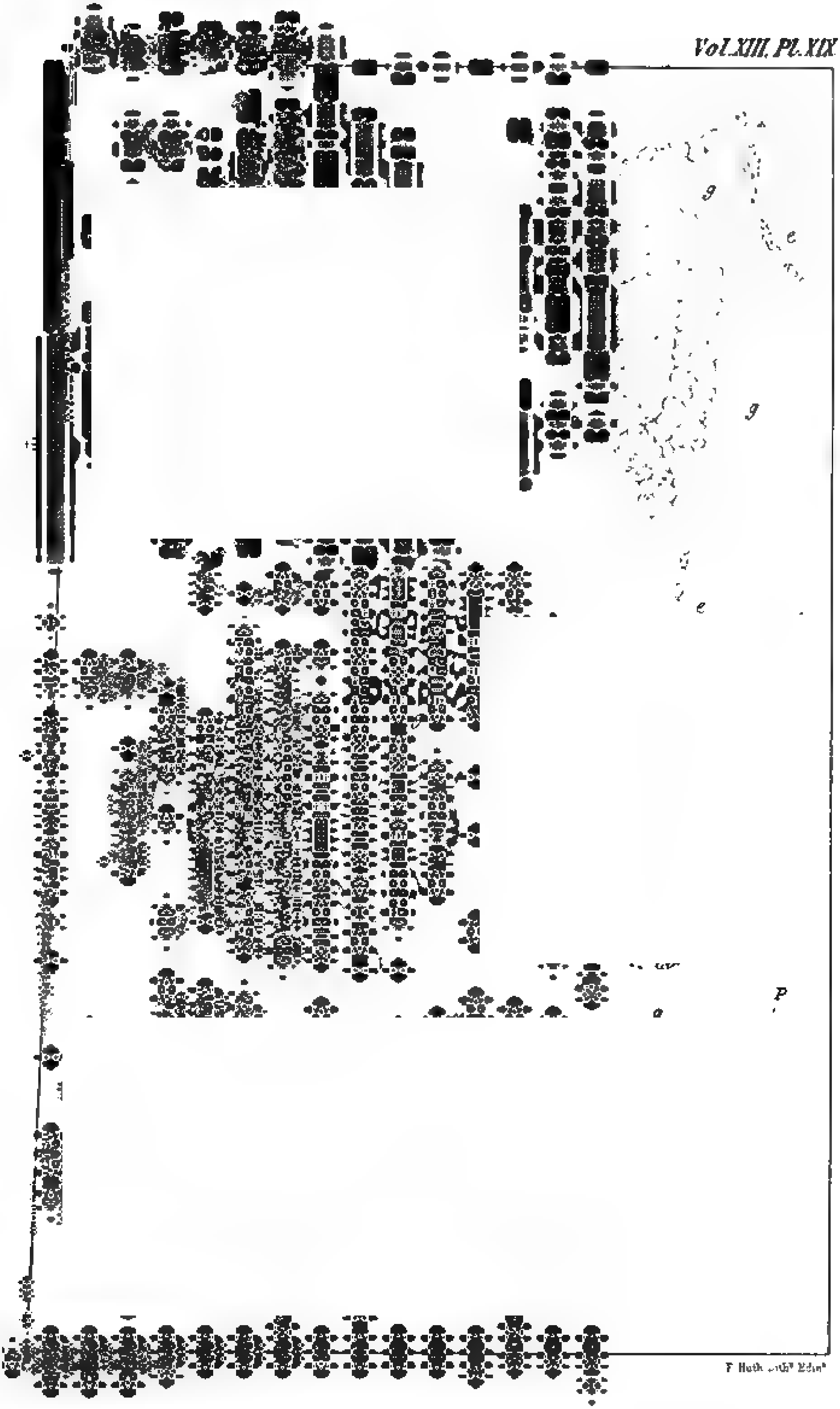

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Fig 8.

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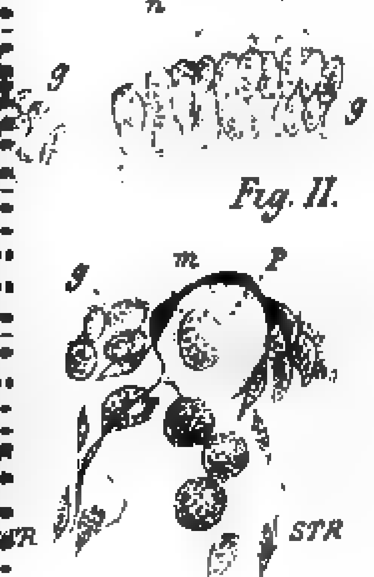
Fig. 11.



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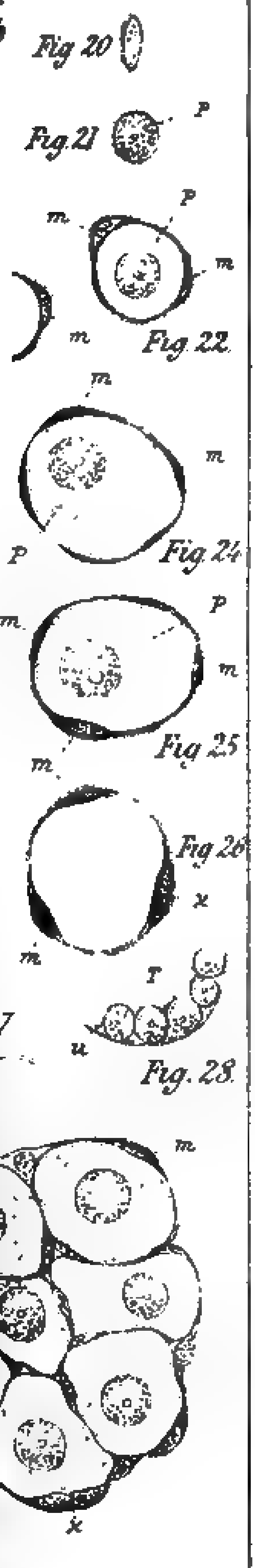

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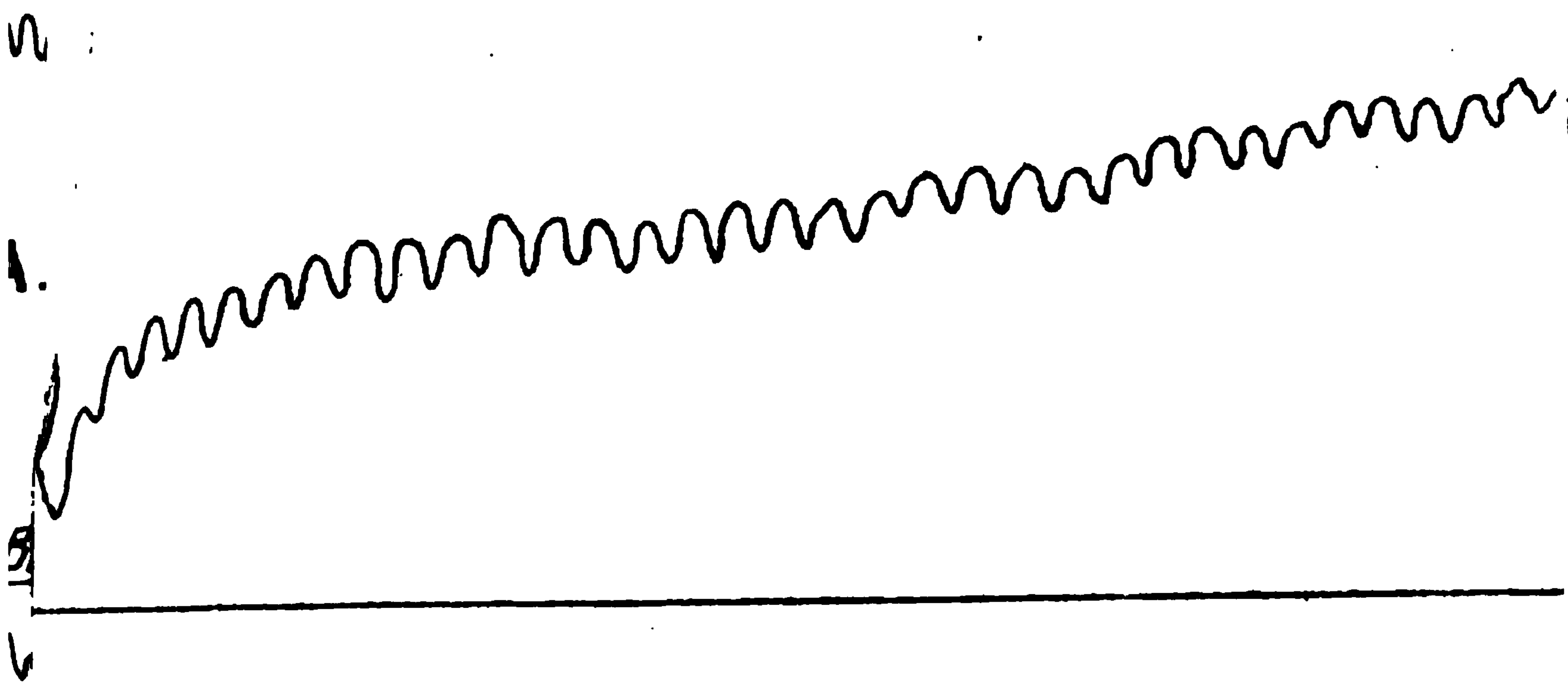

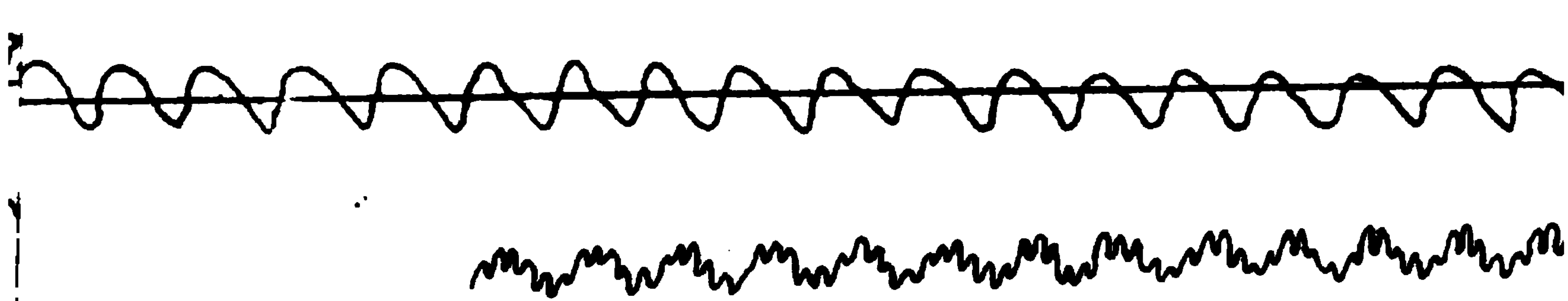

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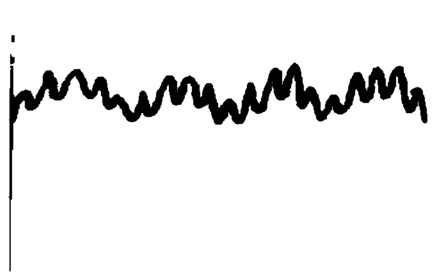

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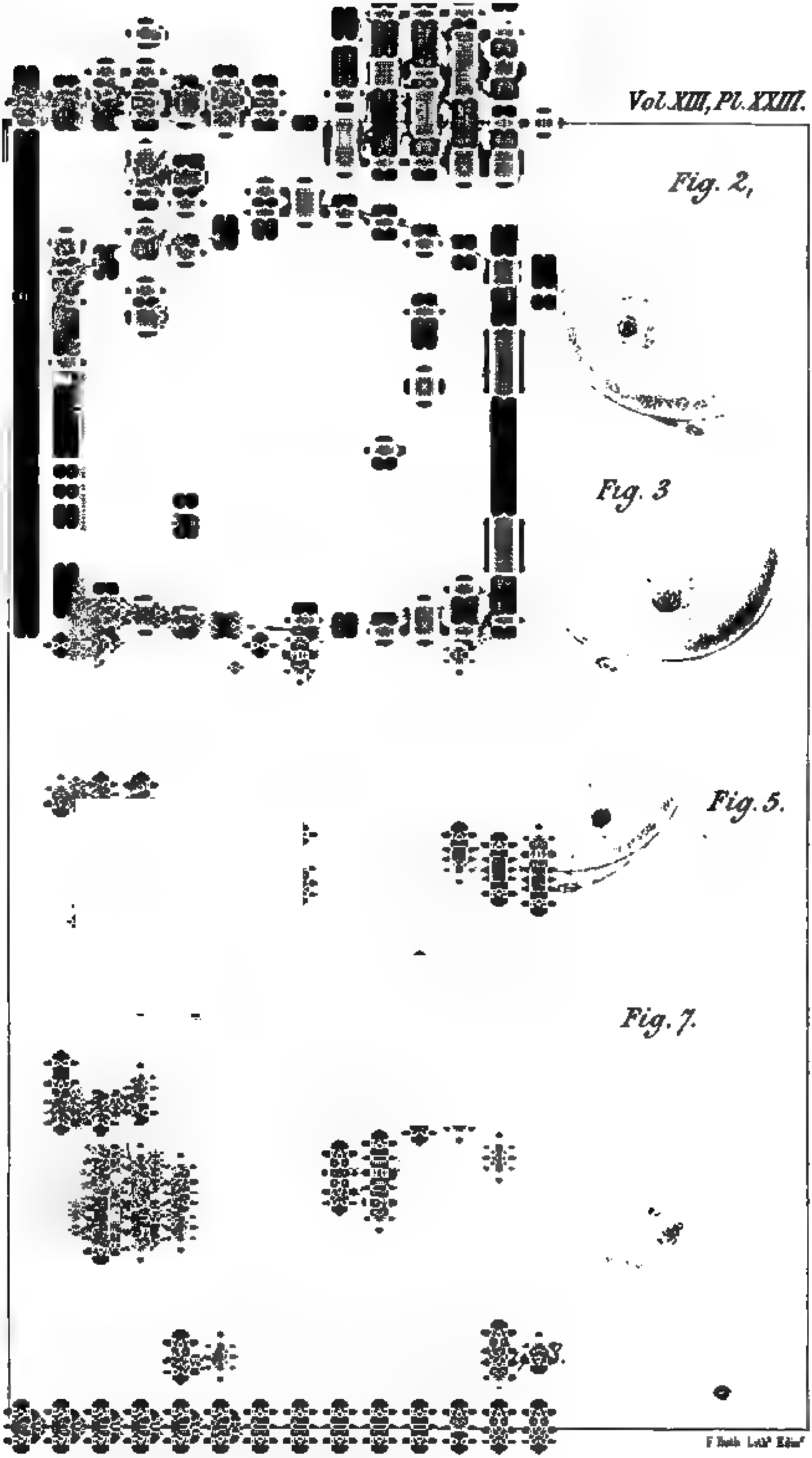

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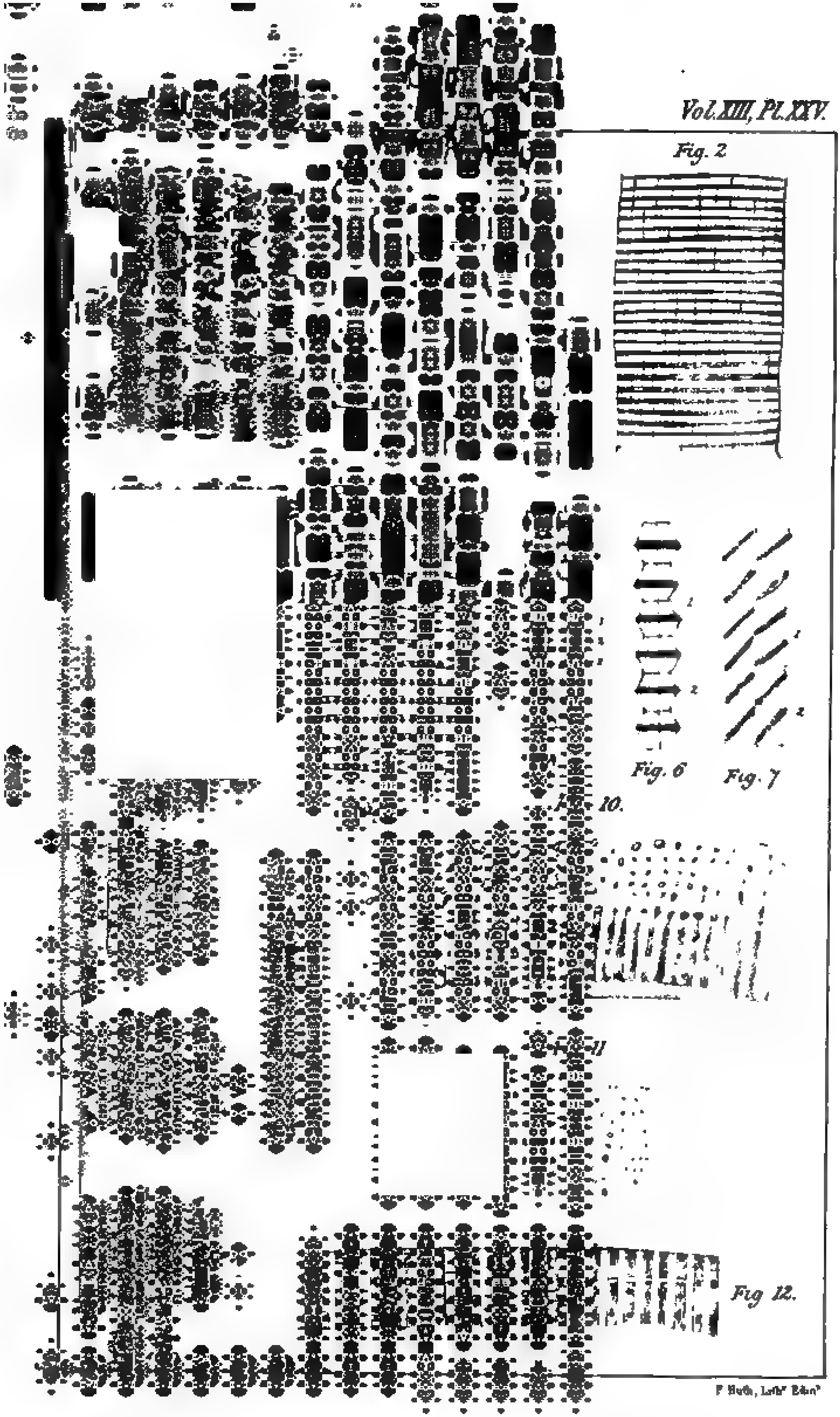

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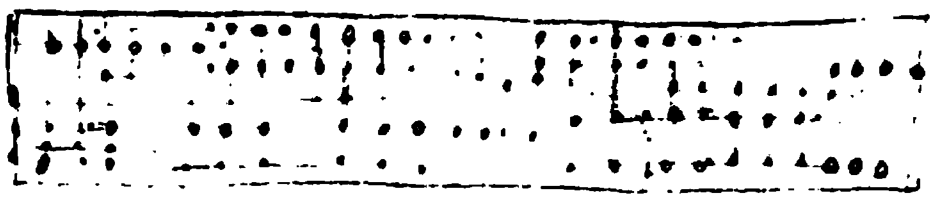

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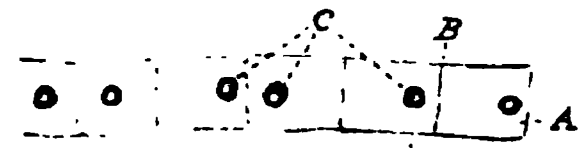

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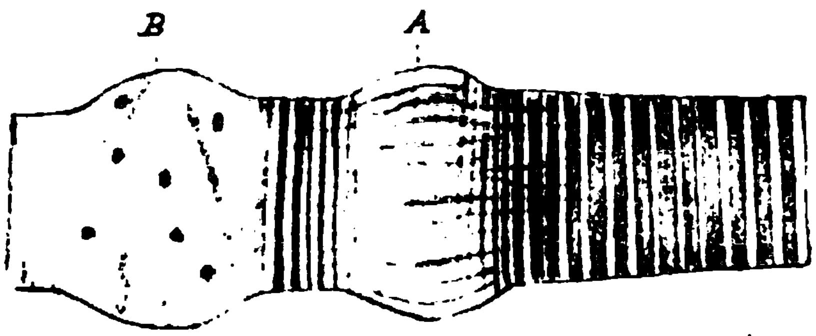

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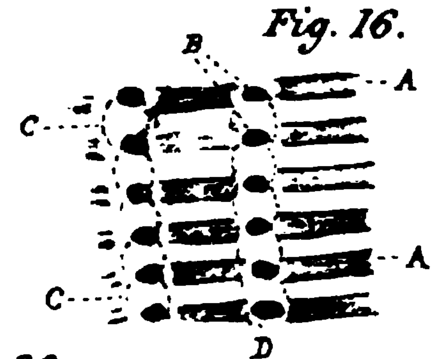

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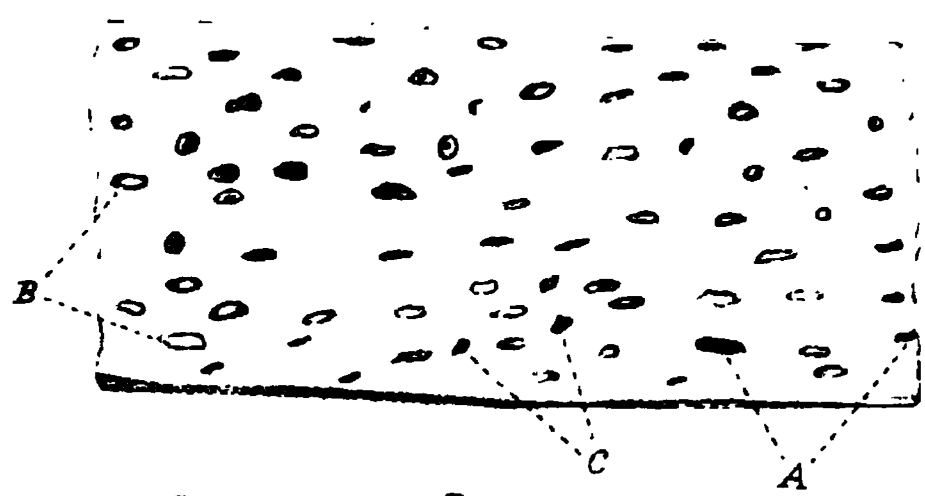

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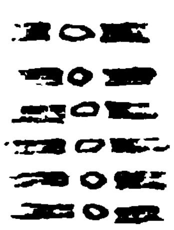

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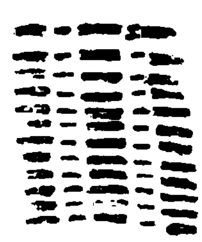

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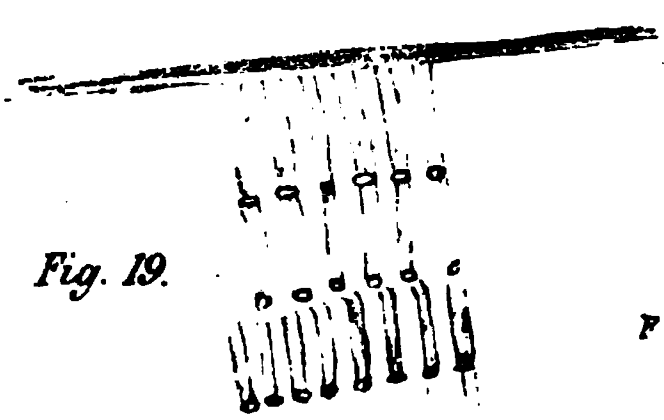

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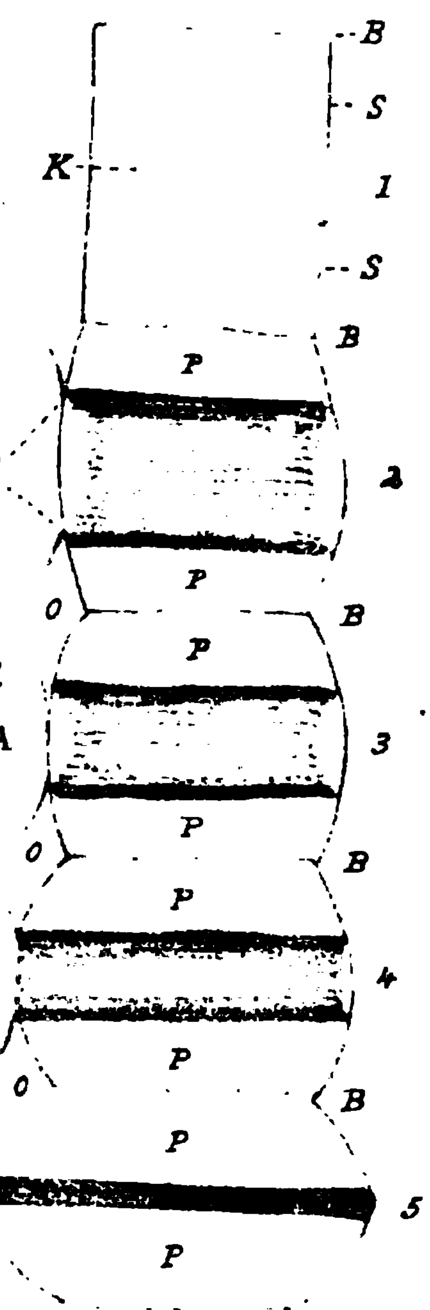

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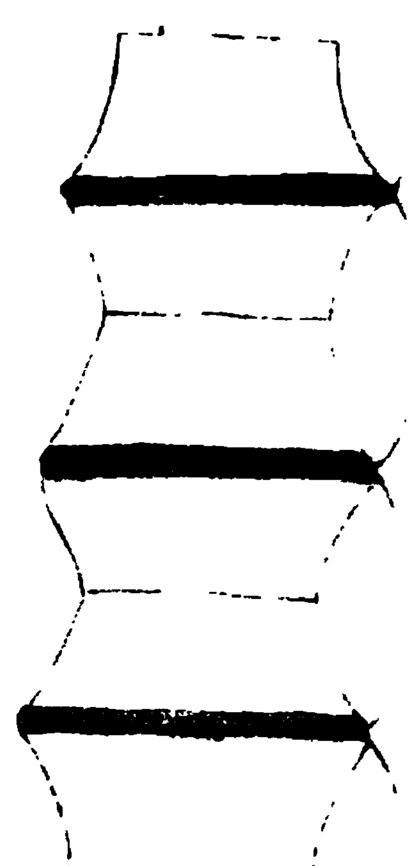

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